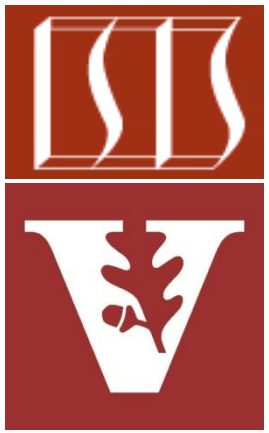
Overview of Java Threads (Part 2)



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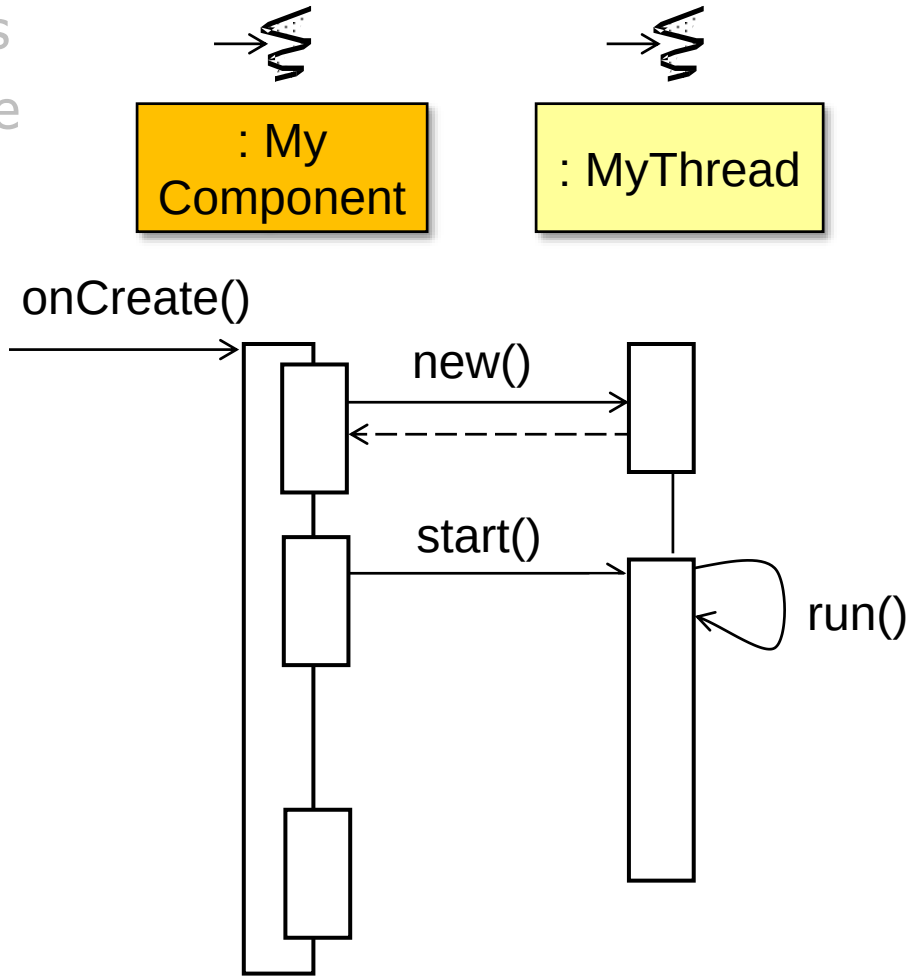
Learning Objectives in this Part of the Lesson

- Understand how Java threads support concurrency
- Learn how our case study app works
- Know alternative ways of giving code to a thread
- Learn how to pass parameters to a Java thread
- Know how to run a Java thread



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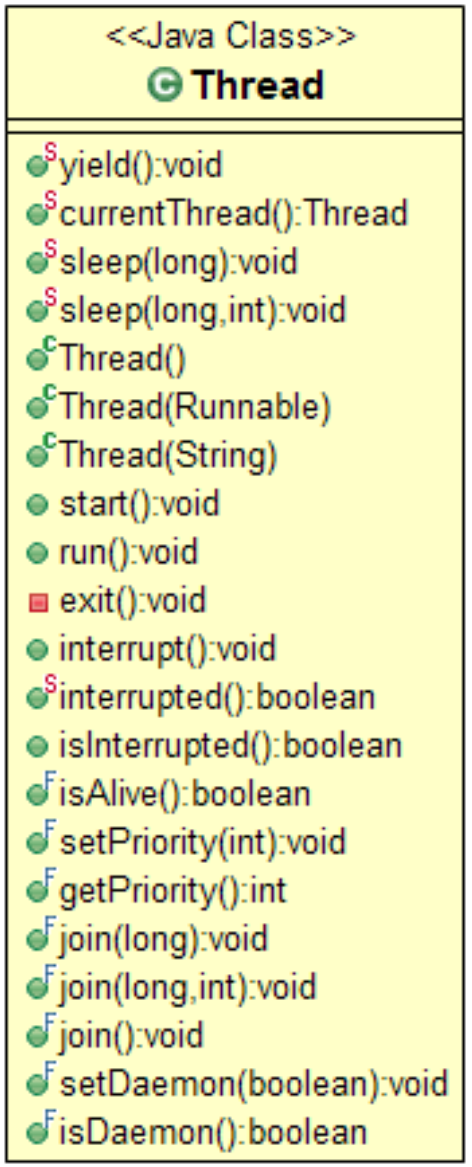

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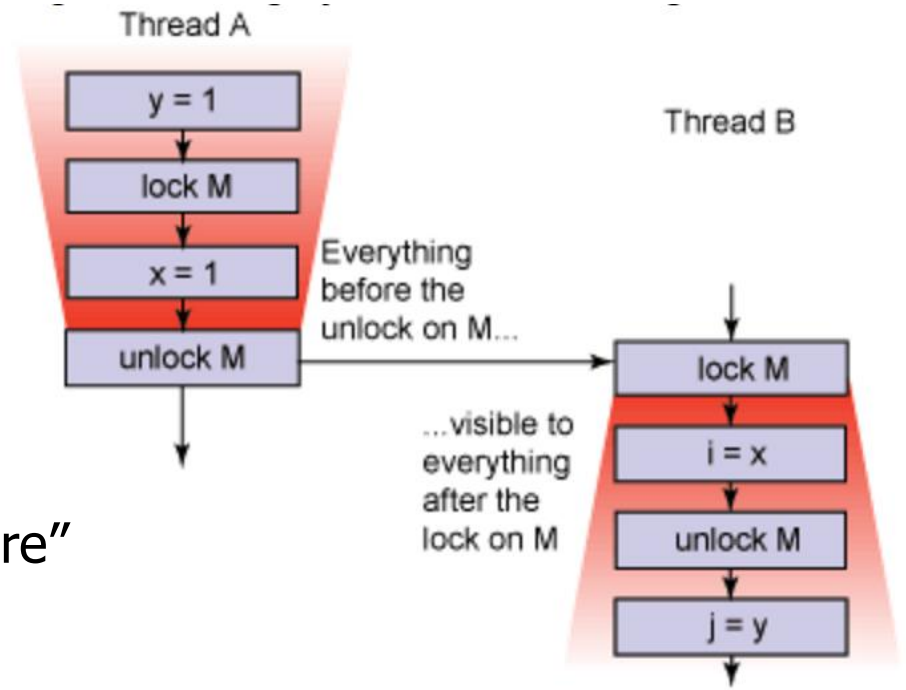
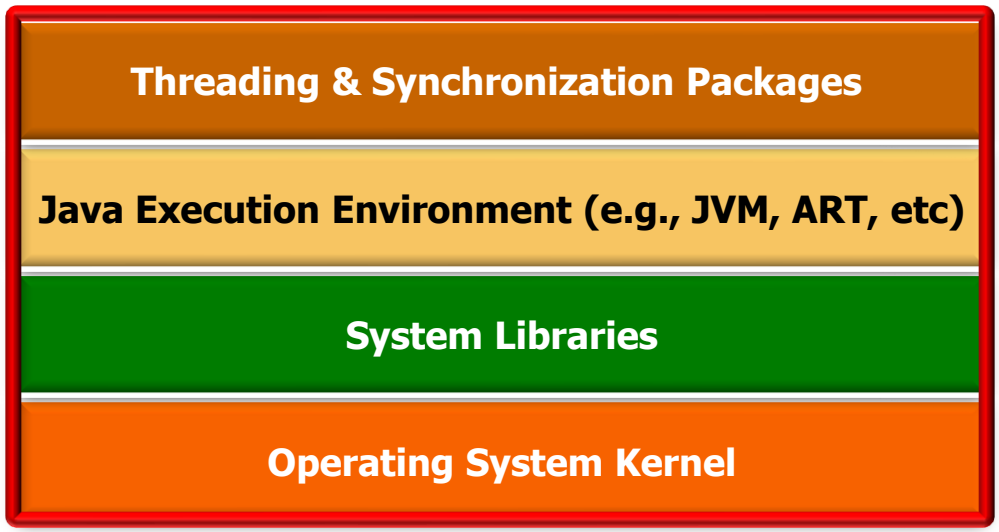
- Appreciate Java thread "happens-before" orderings

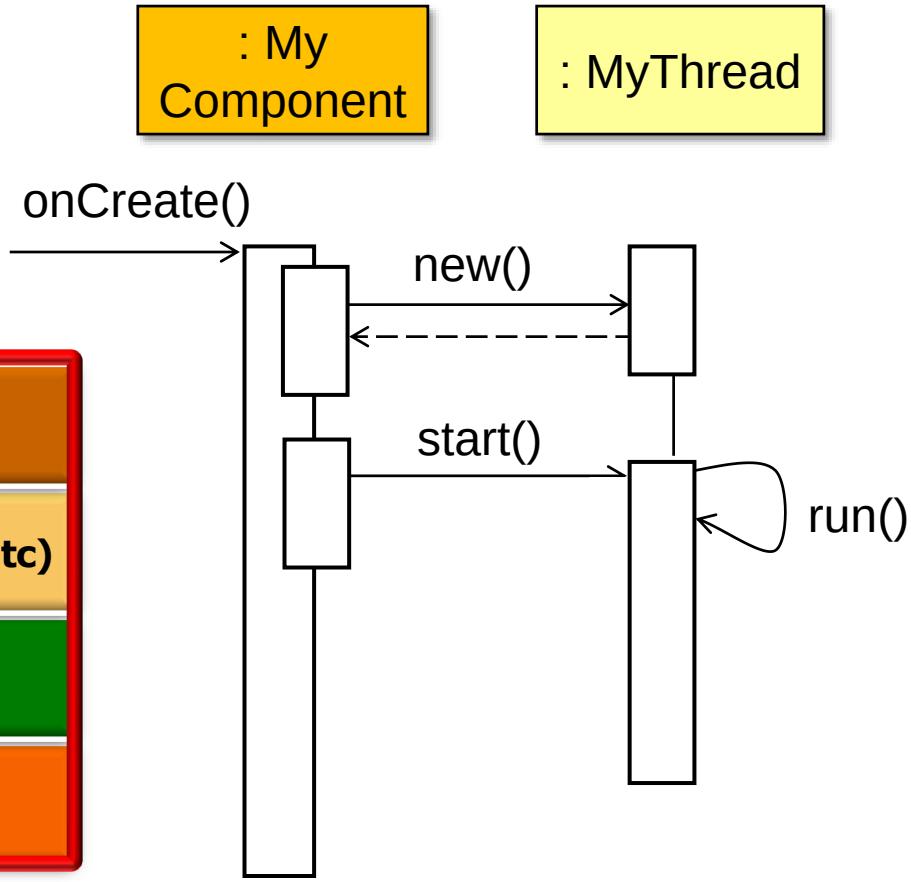


Running Java Threads

Running Java Threads

- There are multiple layers involved in creating & starting a thread

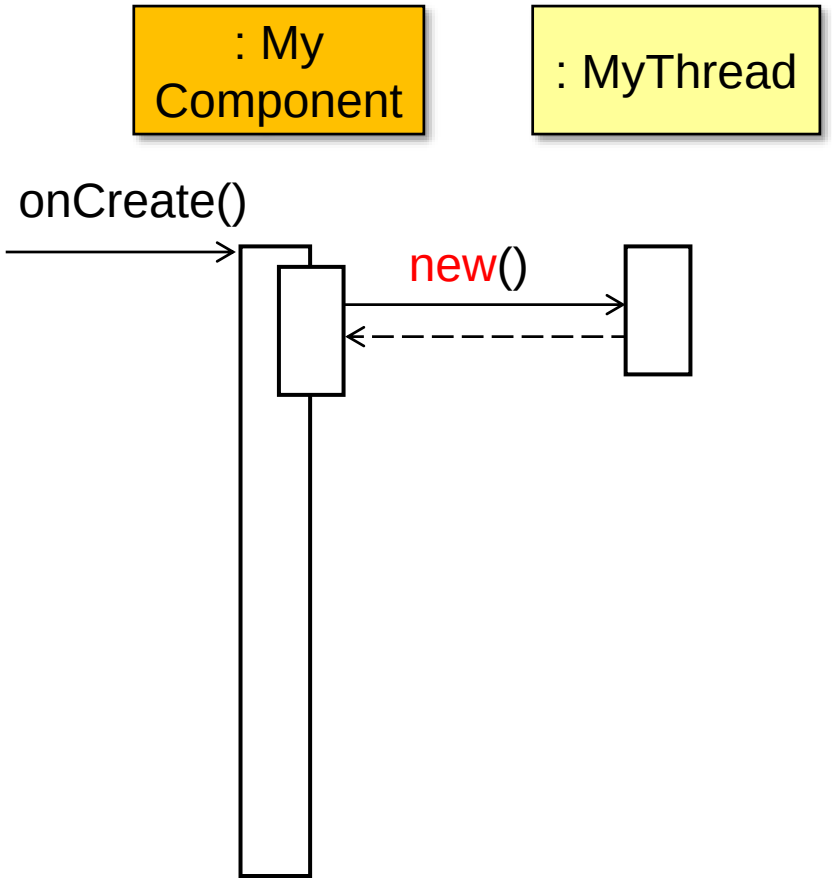




See Part 2 of the upcoming lesson on "Managing the Java Thread Lifecycle"

Running Java Threads

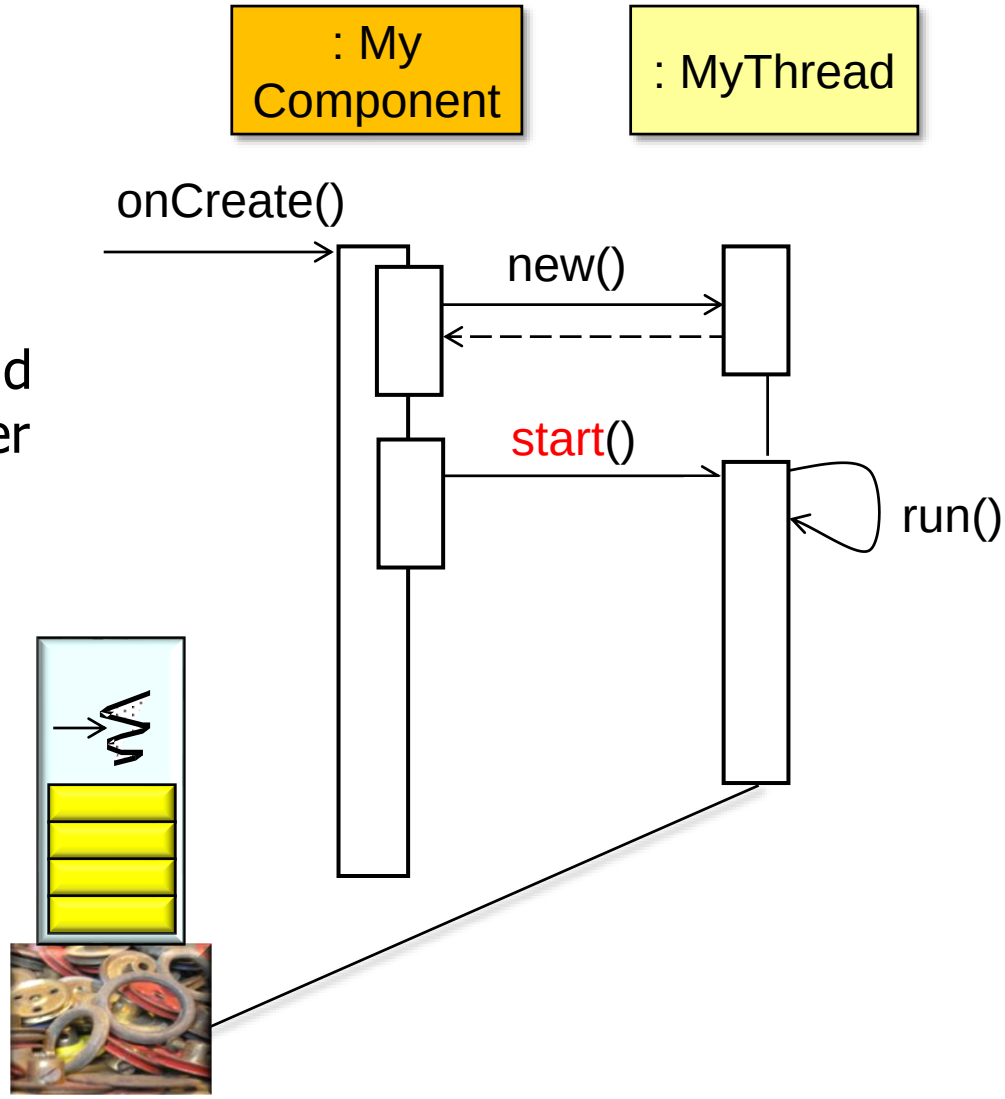
- There are multiple layers involved in creating & starting a thread
  - Creating a new thread object doesn't allocate a run-time call stack of activation records



See en.wikipedia.org/wiki/Call_stack

Running Java Threads

- There are multiple layers involved in creating & starting a thread
  - Creating a new thread object doesn't allocate a run-time call stack of activation records
  - The runtime stack & other thread resources are only allocated after the start() method is called



Running Java Threads

- There are multiple layers involved in creating & starting a thread
  - Creating a new thread object doesn't allocate a run-time call stack of activation records
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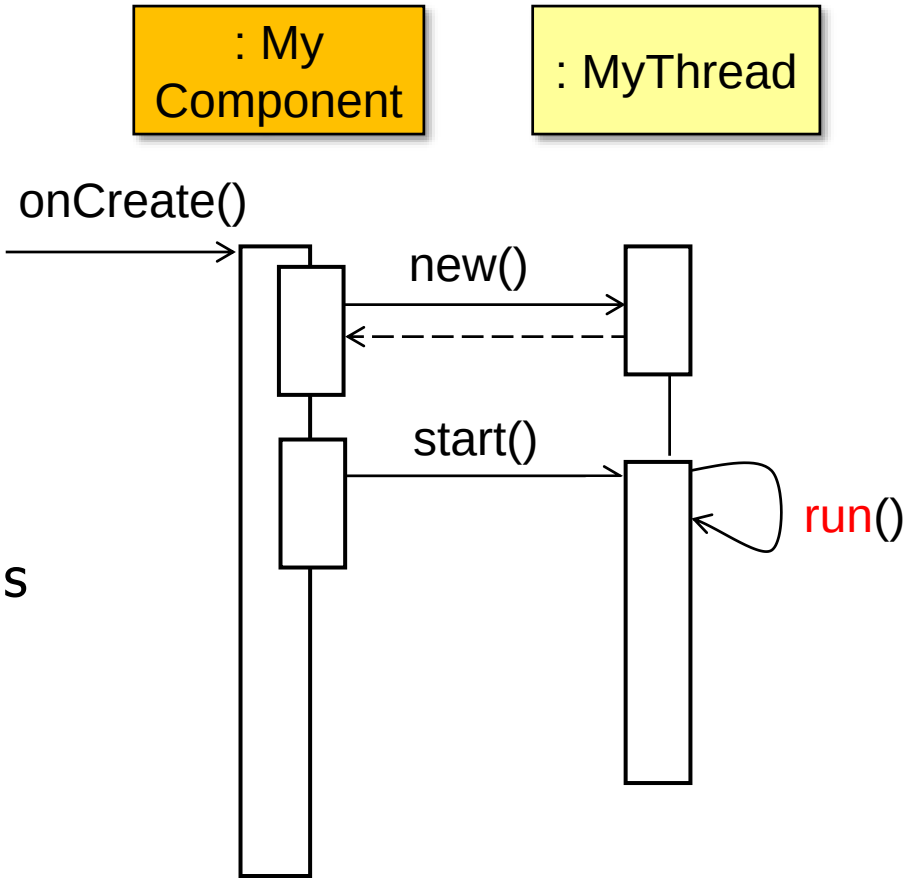
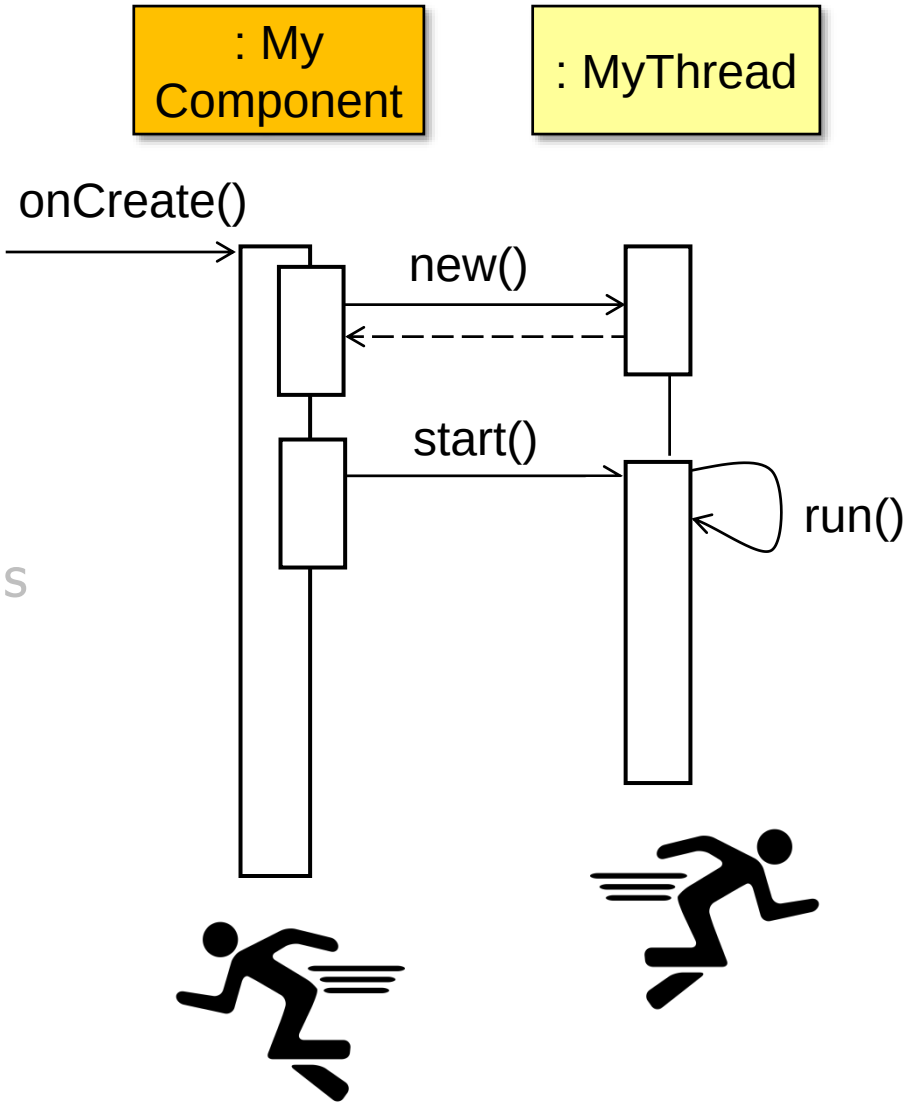
  - The Java execution environment calls a thread's run() hook method after start() creates its resources



See wiki.c2.com/?HookMethod

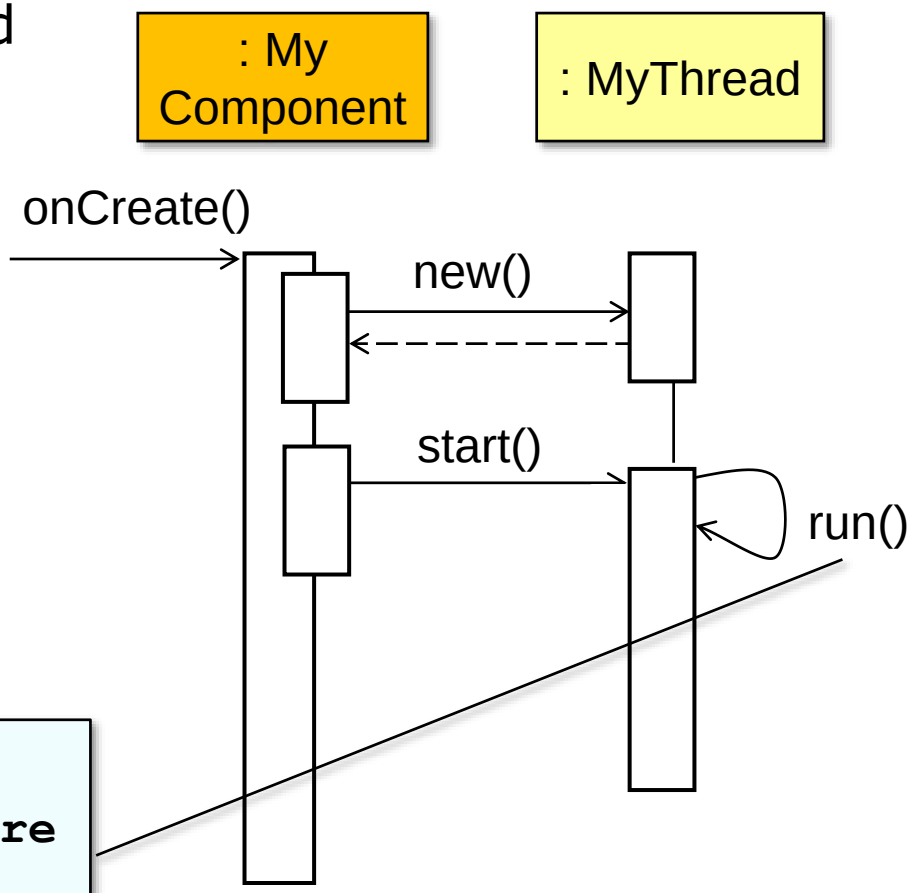
Running Java Threads

- There are multiple layers involved in creating & starting a thread
  - Creating a new thread object doesn't allocate a run-time call stack of activation records
  - The runtime stack & other thread resources are only allocated after the start() method is called
  - The Java execution environment calls a thread's run() hook method after start() creates its resources
  - Each thread can run concurrently & block independently



Running Java Threads

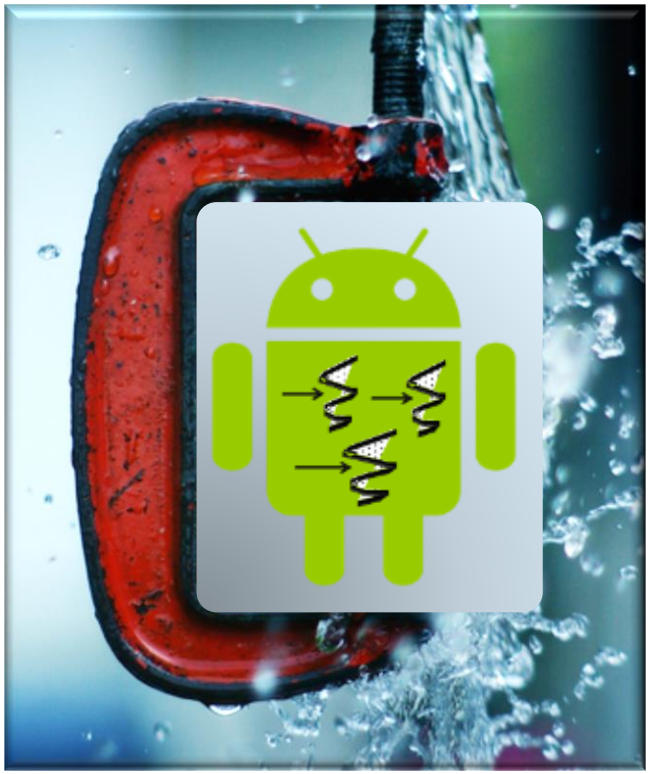
- Any code can generally run in a thread

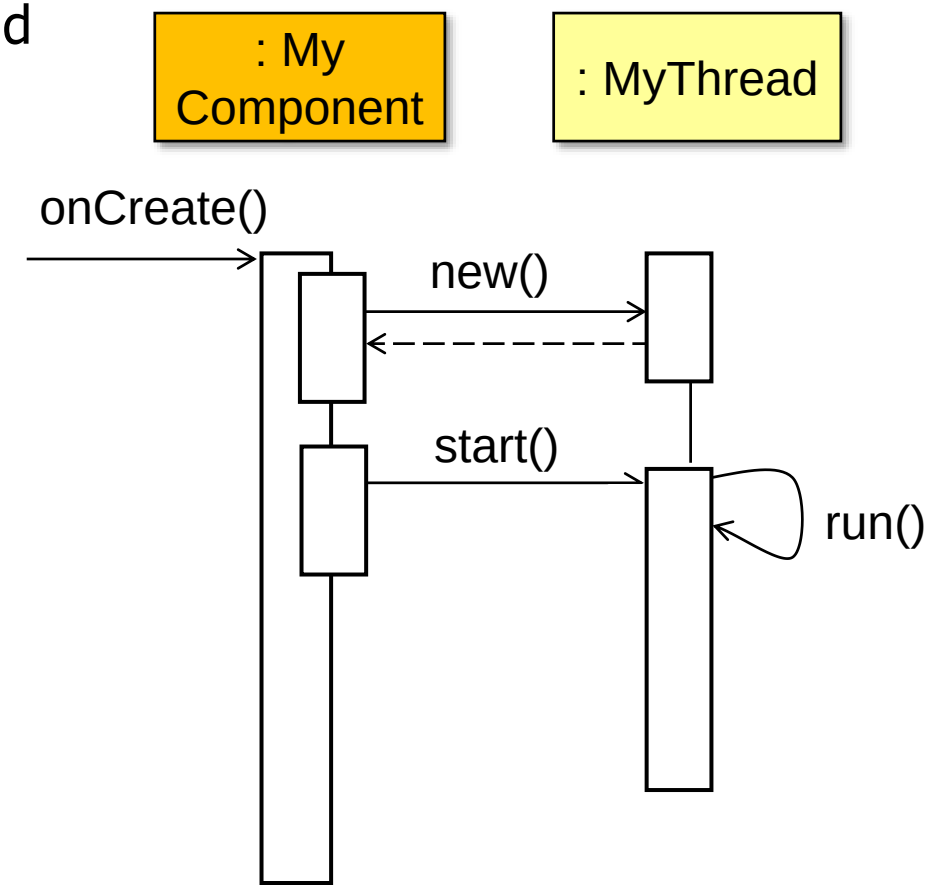



```
public void run(){
   // code to run goes here
}
```

Running Java Threads

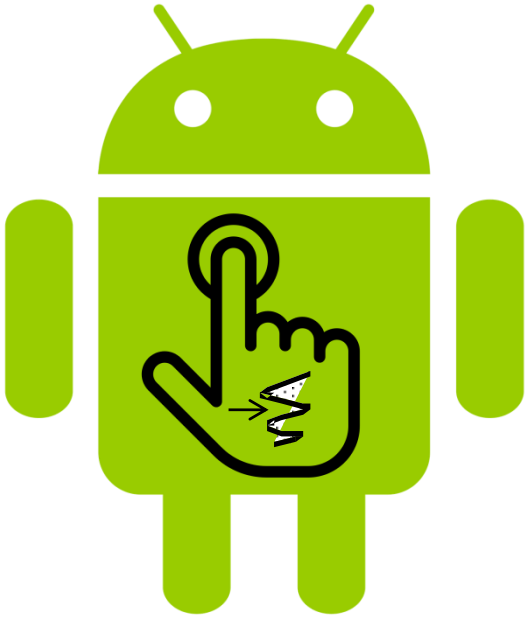
- Any code can generally run in a thread
  - However, windowing toolkits often restrict which thread can access GUI components

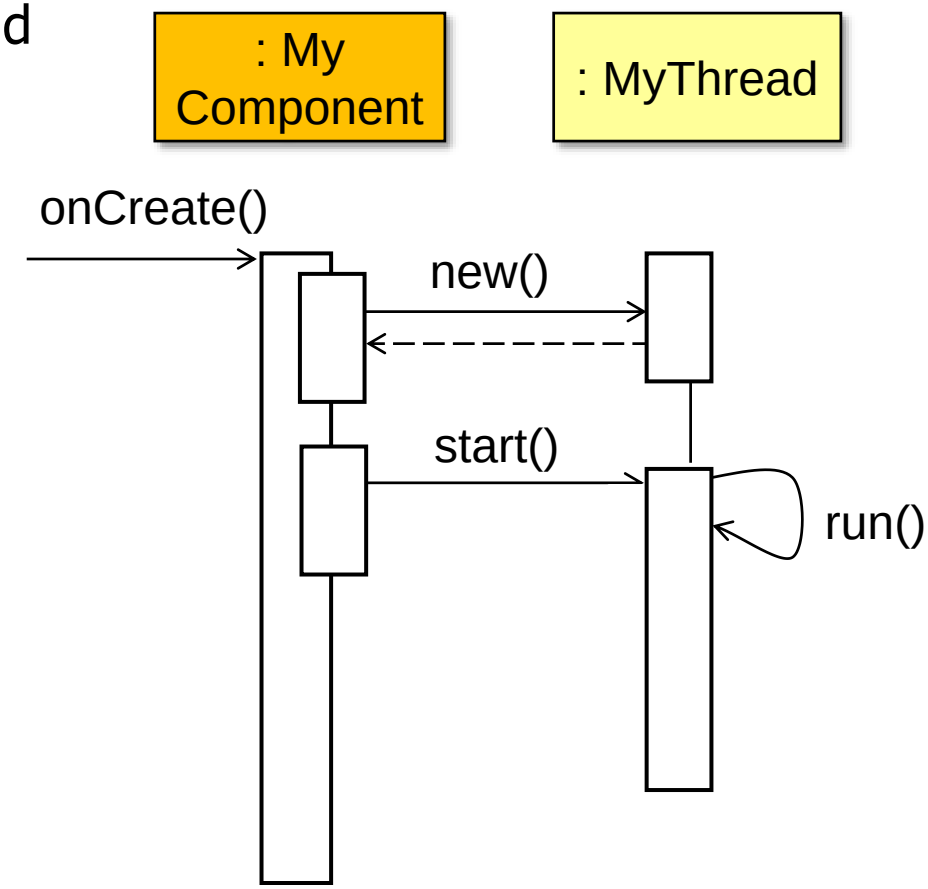




Running Java Threads

- Any code can generally run in a thread
  - However, windowing toolkits often restrict which thread can access GUI components
    - e.g., only the Android UI thread can access GUI components

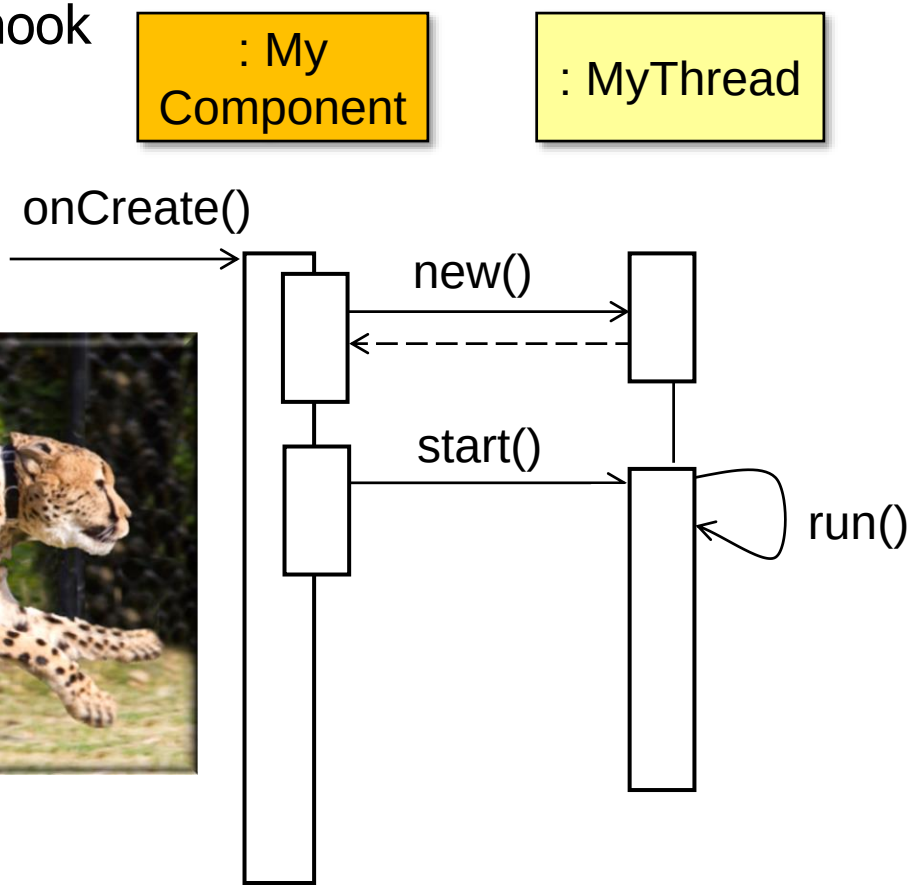




See developer.android.com/training/multiple-threads/communicate-ui.html

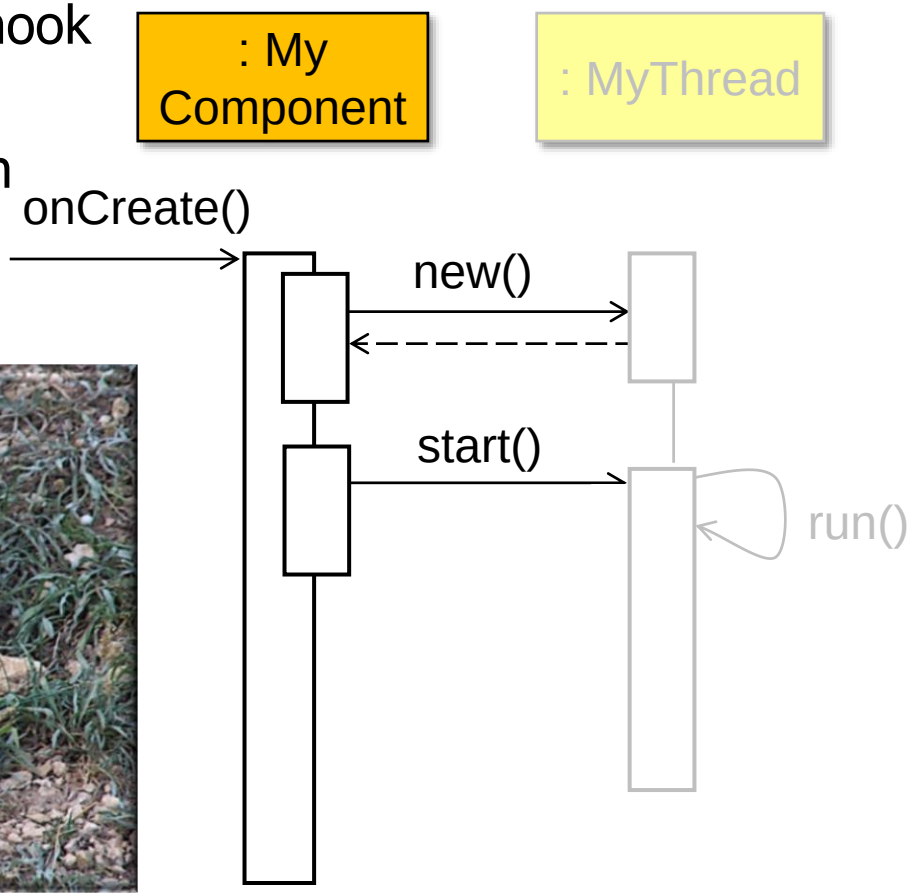
Running Java Threads

- A thread can live as long as its run() hook method hasn't returned



Running Java Threads

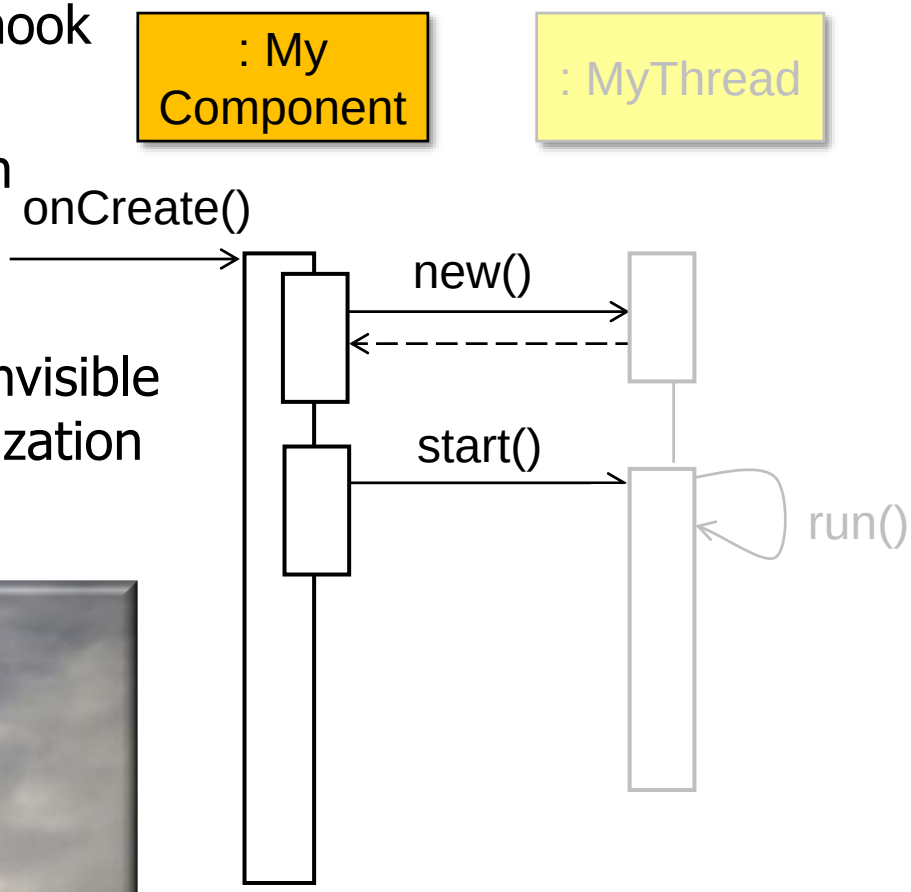
- A thread can live as long as its run() hook method hasn't returned
  - The underlying thread scheduler can suspend & resume a thread many times during its lifecycle



See en.wikipedia.org/wiki/Scheduling_(computing)

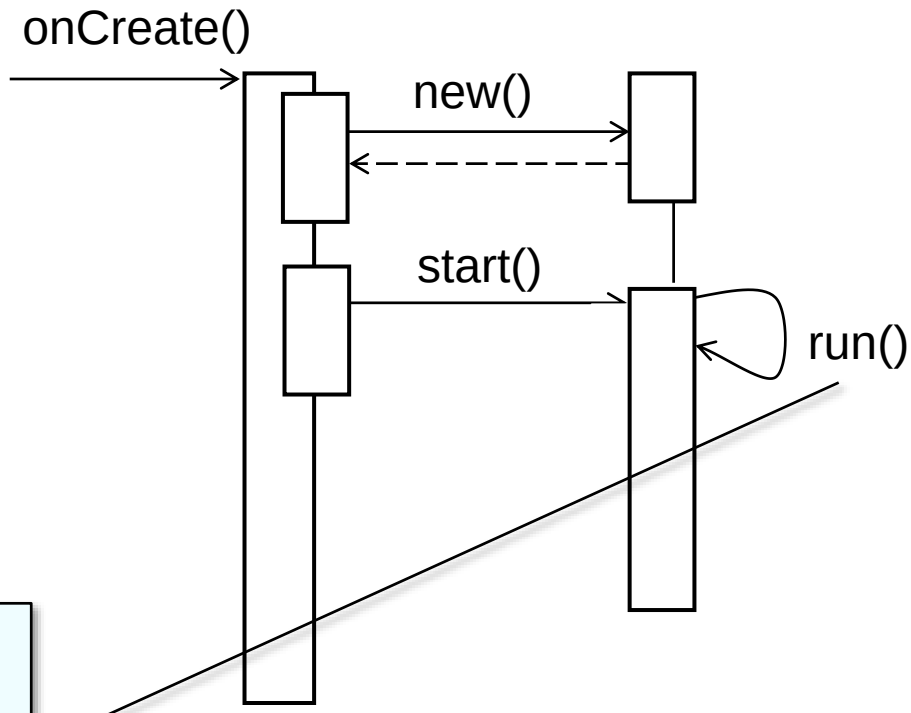
Running Java Threads

- A thread can live as long as its run() hook method hasn't returned
  - The underlying thread scheduler can suspend & resume a thread many times during its lifecycle
    - Scheduler operations are largely invisible to user code, as long as synchronization is performed properly..



Running Java Threads

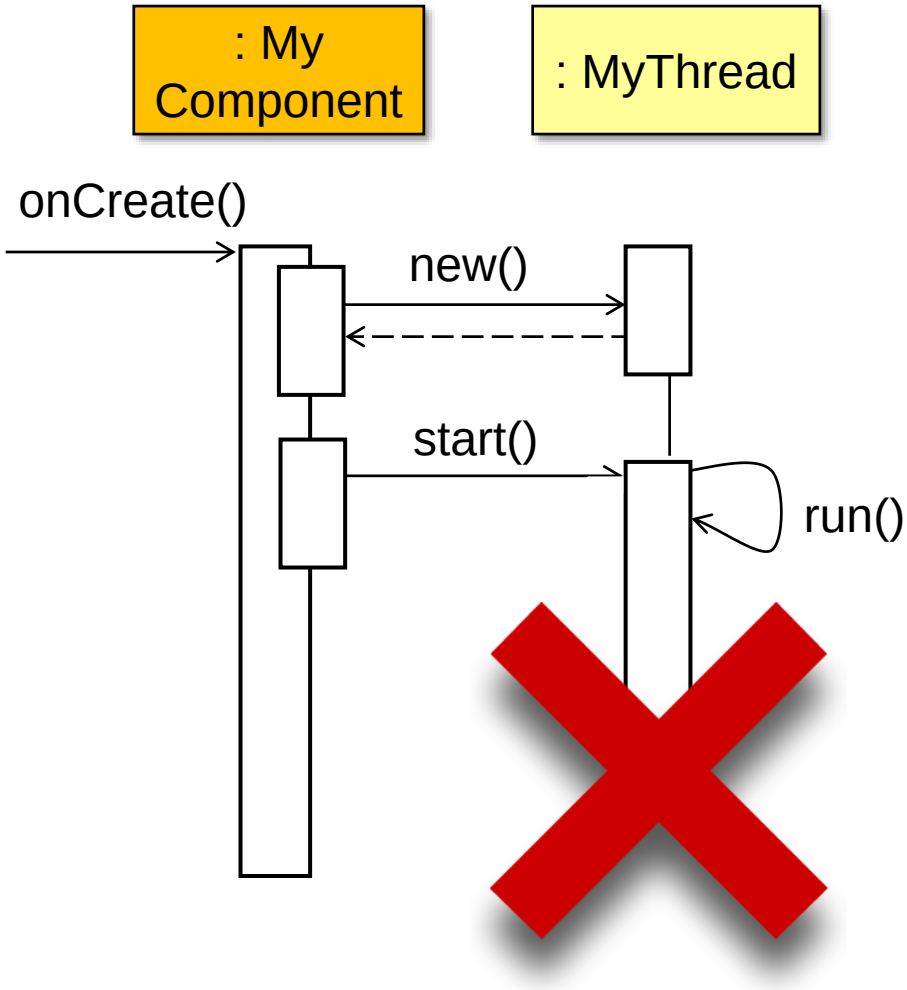
- For a thread to execute "forever," its run() hook method needs an infinite loop




```
public void run(){
   while (true) { ... }
}
```

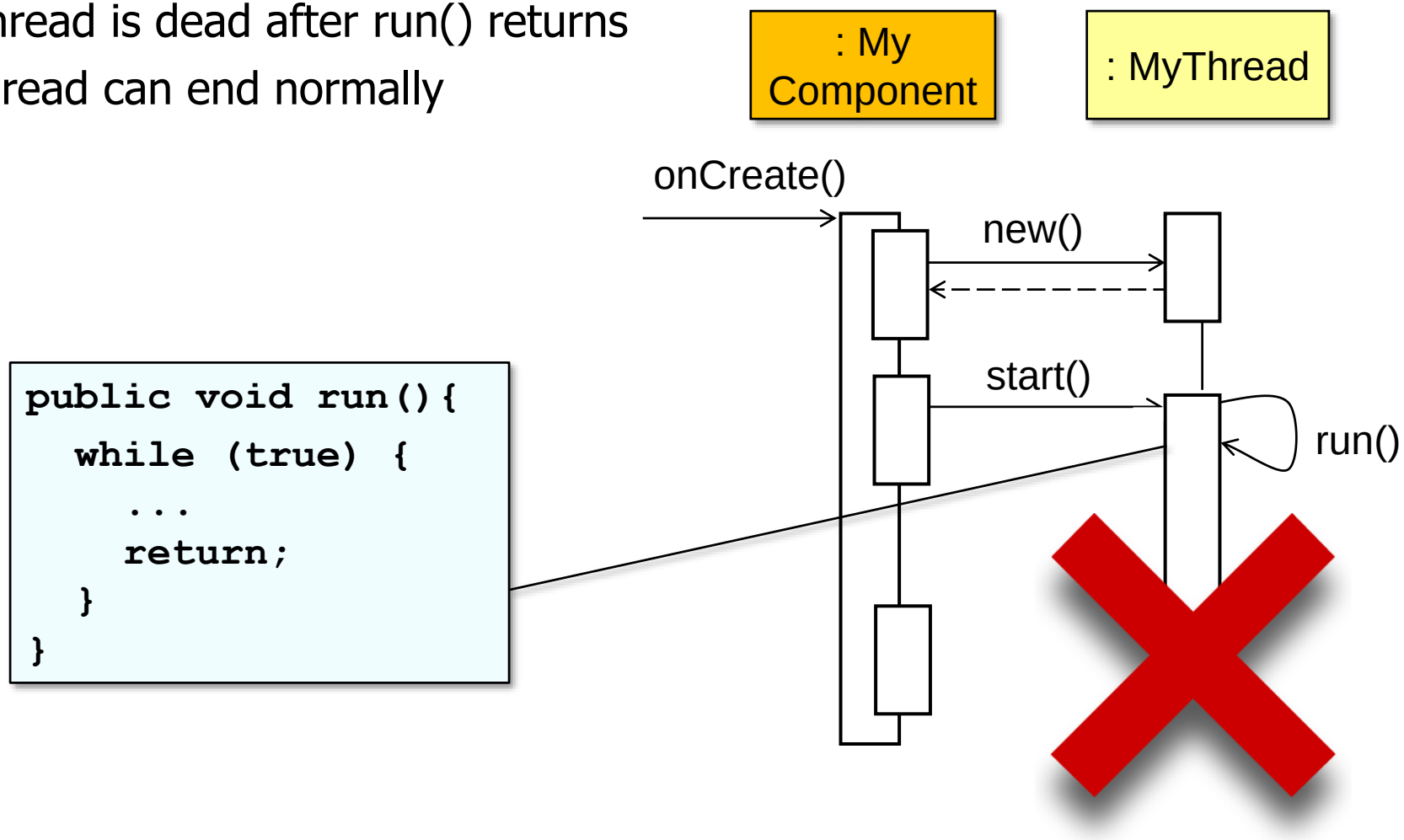
Running Java Threads

- The thread is dead after run() returns



Running Java Threads

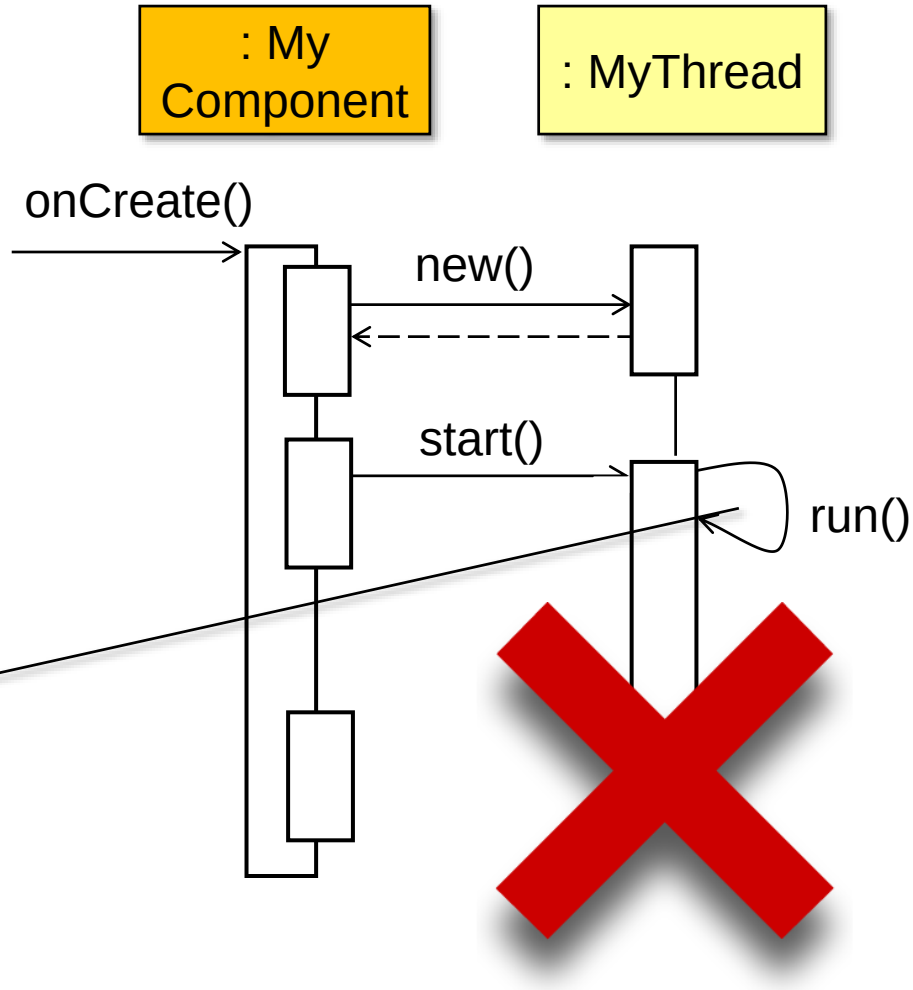
- The thread is dead after run() returns
  - A thread can end normally



Running Java Threads

- The thread is dead after run() returns
  - A thread can end normally
  - Or an uncaught exception can be thrown

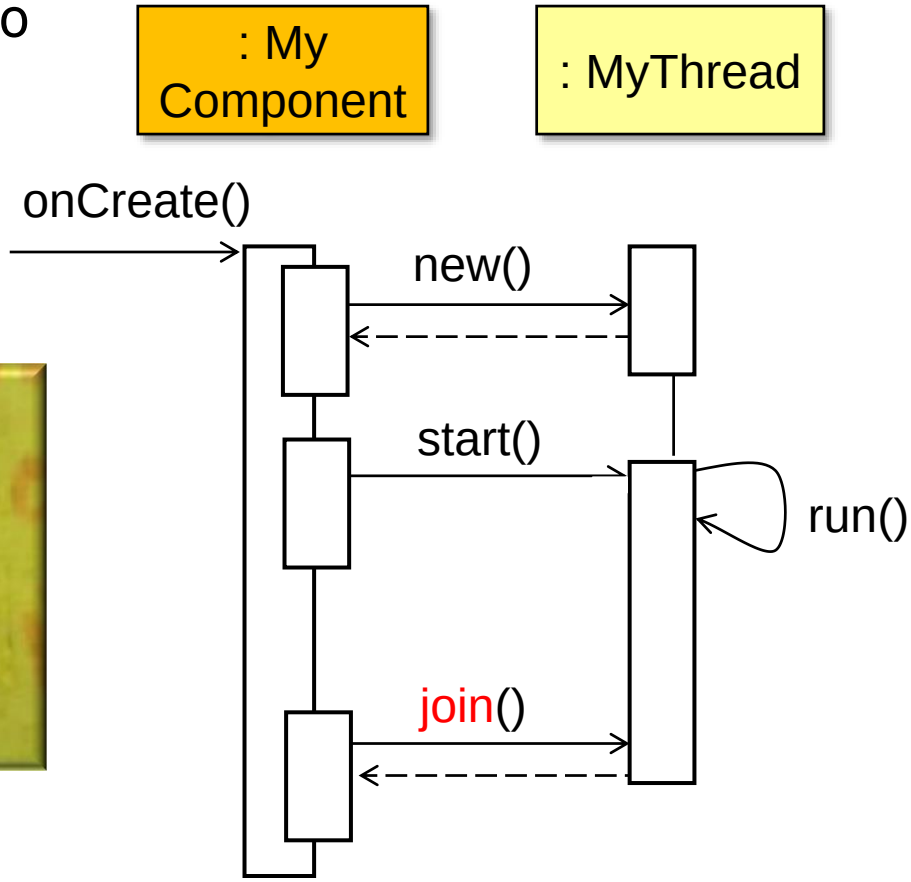
```
public void run(){
   while (true) {
      ...
      throw new
        SomeException();
   }
}
```



See www.javamex.com/tutorials/exceptions/exceptions_uncaught_handler.shtml

Running Java Threads

- The join() method allows one thread to wait for another thread to complete



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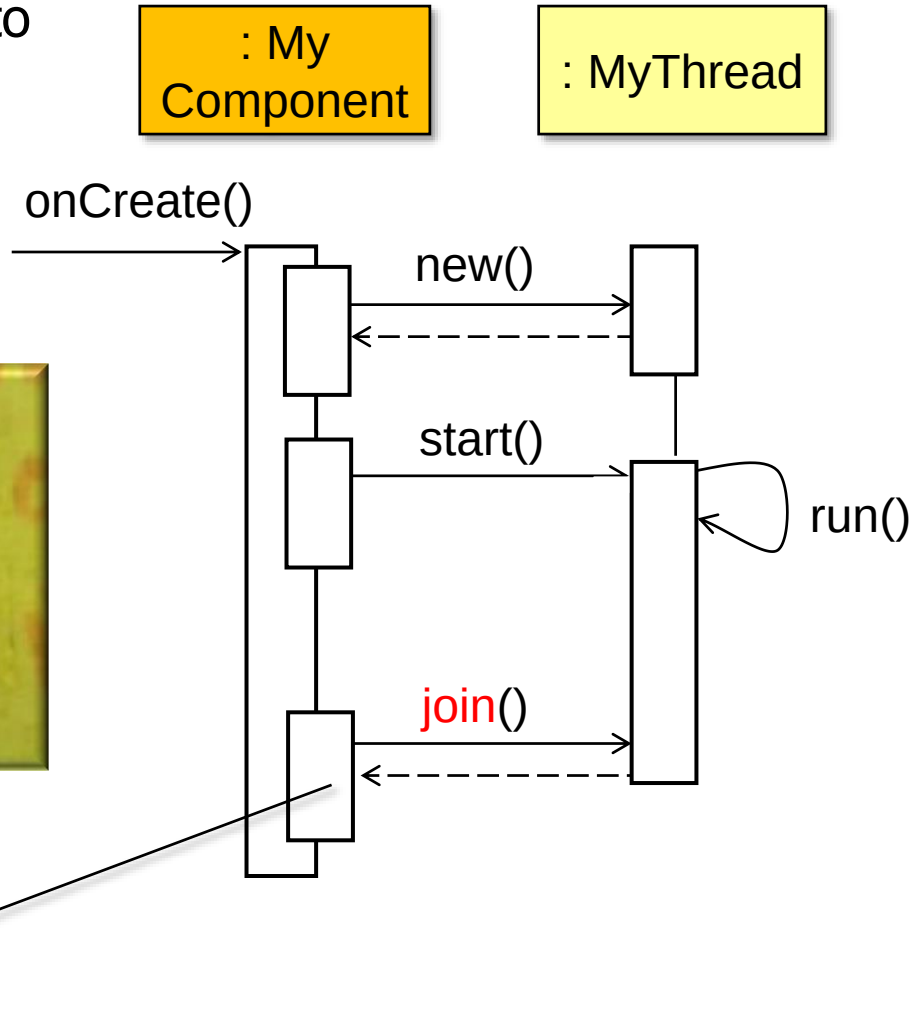
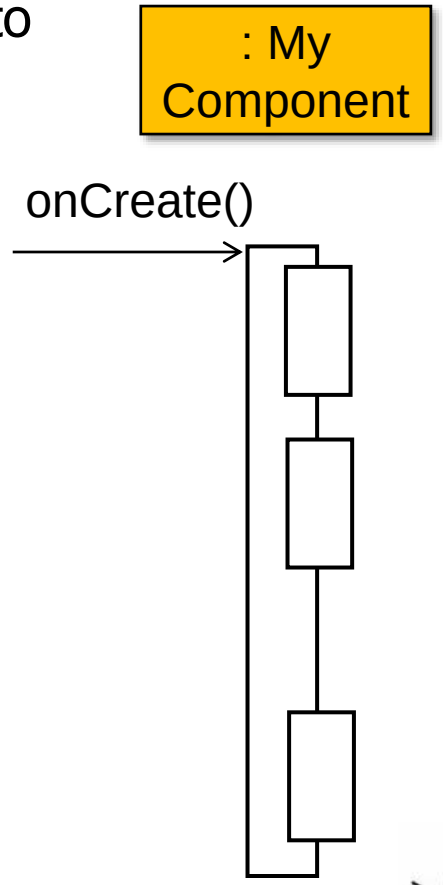


See upcoming lessons on "Java Barrier Synchronizers"

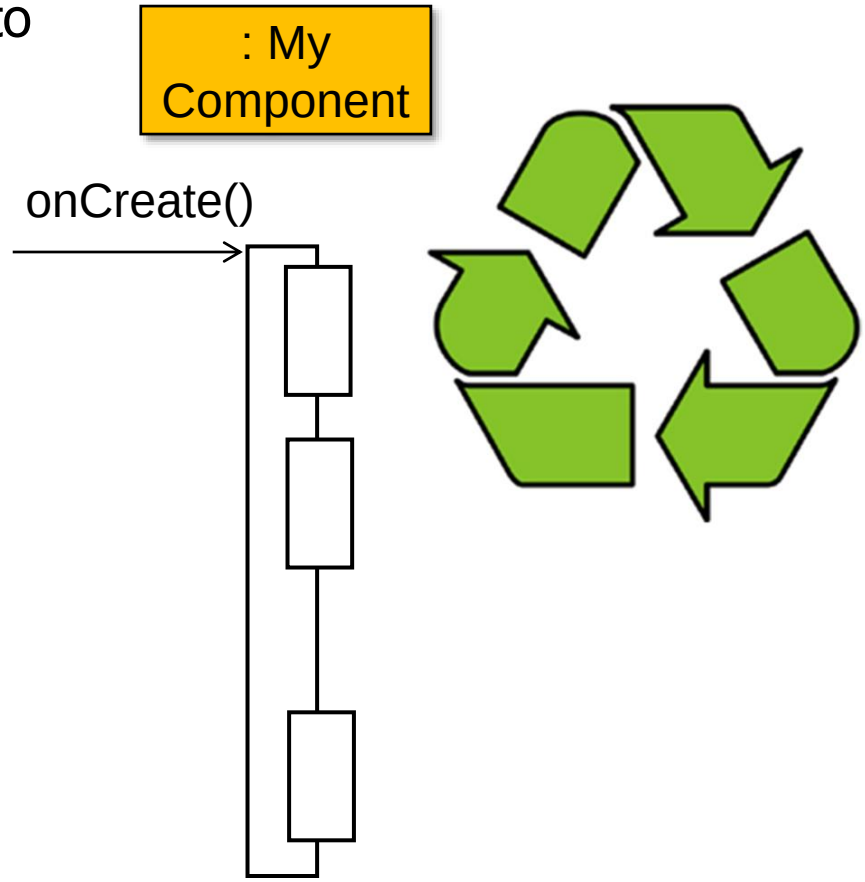
Running Java Threads

- The join() method allows one thread to wait for another thread to complete
  - Or a thread can simply evaporate!



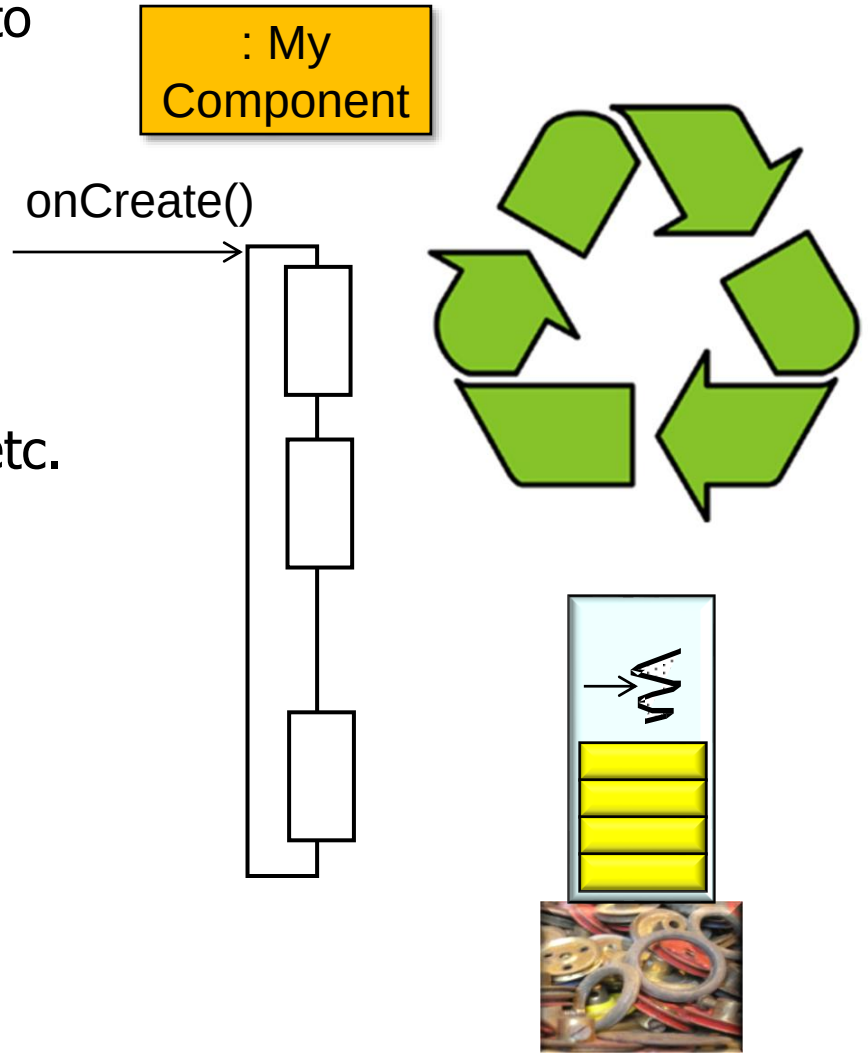
Running Java Threads

- The join() method allows one thread to wait for another thread to complete
  - Or a thread can simply evaporate!
  - The Java execution environment recycles thread resources



Running Java Threads

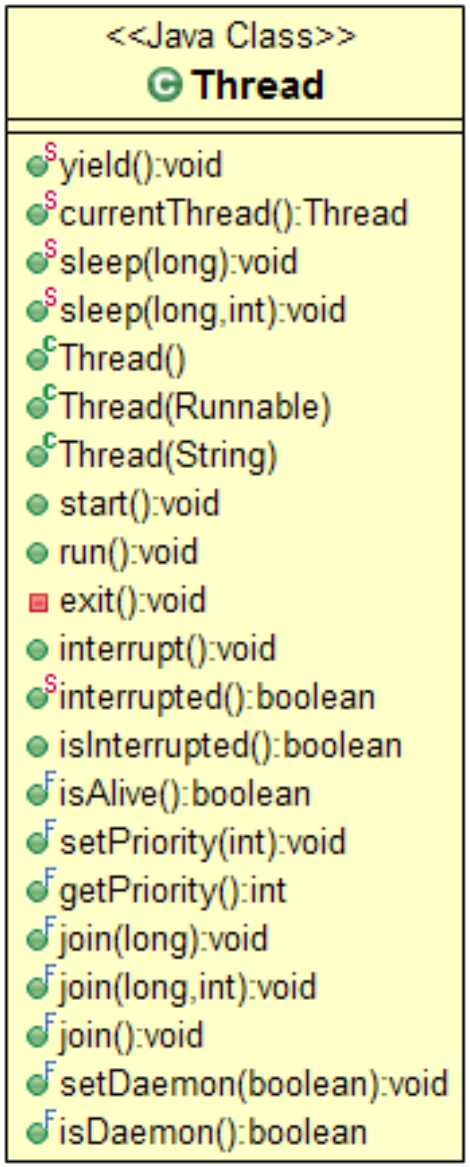
- The join() method allows one thread to wait for another thread to complete
  - Or a thread can simply evaporate!
  - The Java execution environment recycles thread resources
    - e.g., runtime stack of activation records, thread-specific storage, etc.



Some Common Java Thread Methods

Some Common Java Thread Methods

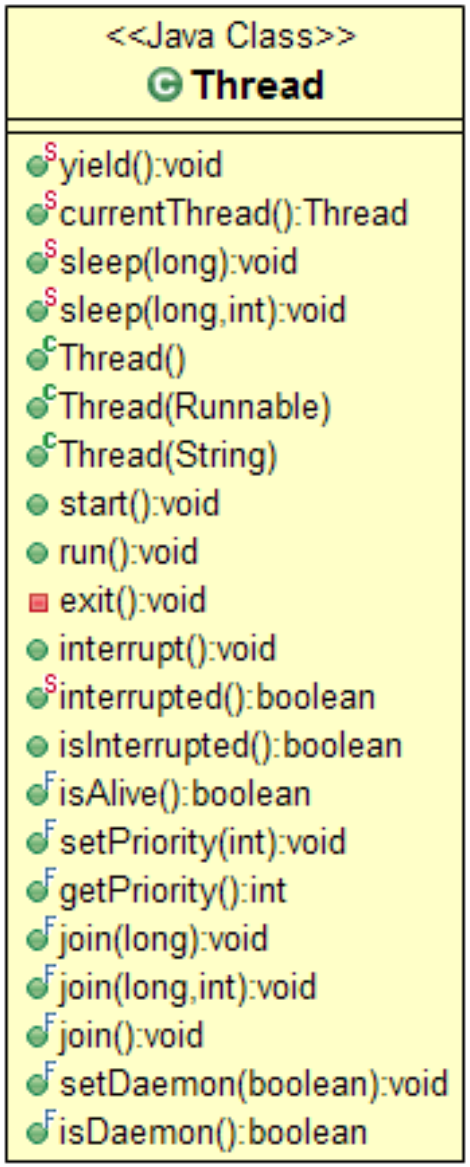
- There are a number of commonly used methods in the Java Thread class



See docs.oracle.com/javase/8/docs/api/java/lang/Thread.html

Some Common Java Thread Methods

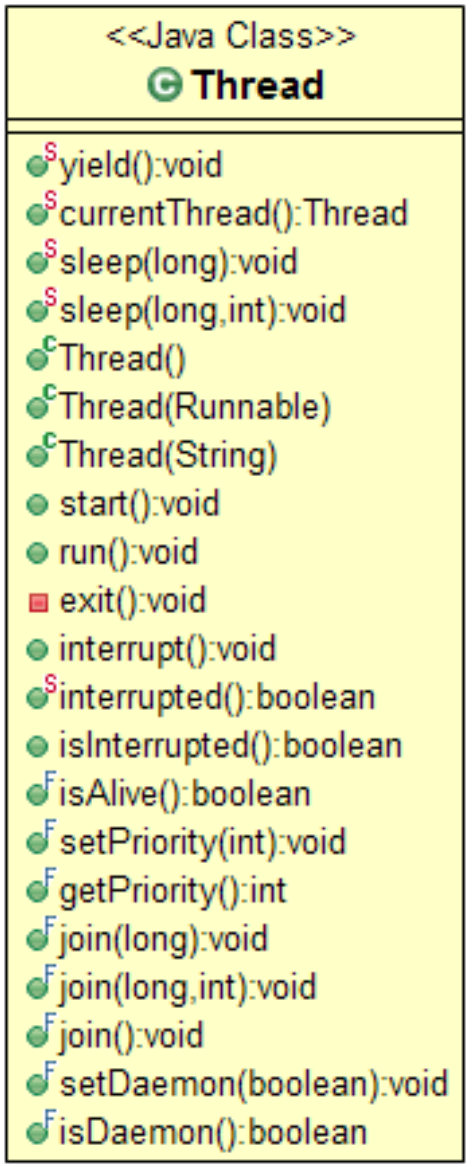
- There are a number of commonly used methods in the Java Thread class, e.g.,
  - **`void setDaemon()`**
    - Marks thread as a "daemon"



See javarevisited.blogspot.com/2012/03/what-is-daemon-thread-in-java-and.html

Some Common Java Thread Methods

- There are a number of commonly used methods in the Java Thread class, e.g.,
  - `void setDaemon()`
  - **`void start()`**
    - Allocates thread resources & initiates thread execution by calling the run() hook method



Some Common Java Thread Methods

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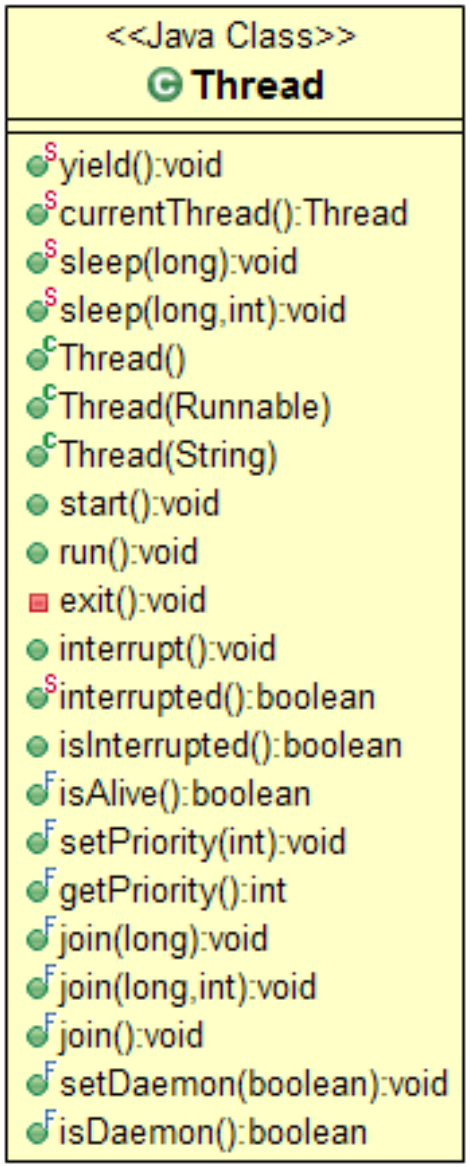
  - `void setDaemon()`
  - `void start()`
  - **`void run()`**
    - Hook method where user code is supplied



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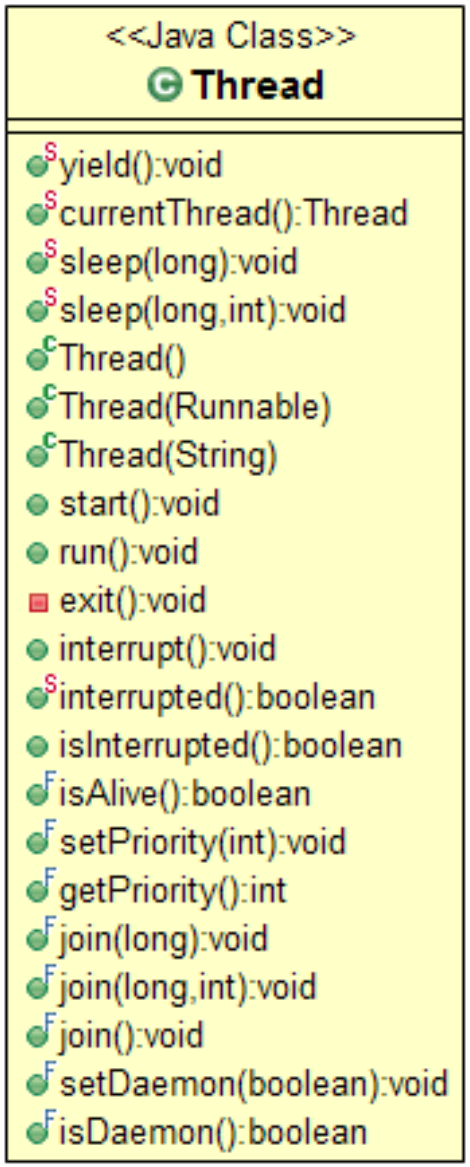
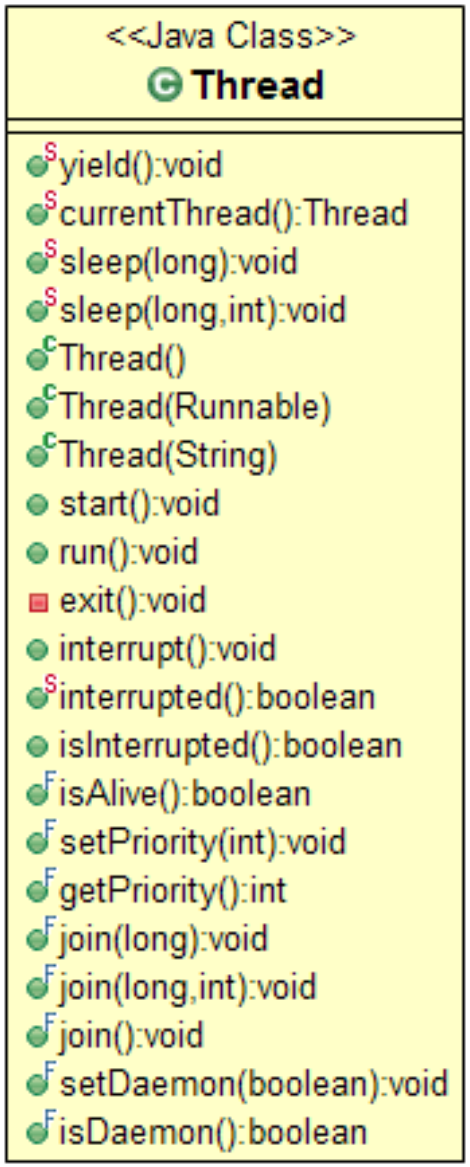
  - **`void join()`**
    - Waits for a thread to finish



A simple form of "barrier synchronization"

Some Common Java Thread Methods

- There are a number of commonly used methods in the Java Thread class, e.g.,
  - `void setDaemon()`
  - `void start()`
  - `void run()`
  - `void join()`
  - **`void sleep(long time)`**
    - Sleeps for given time in ms



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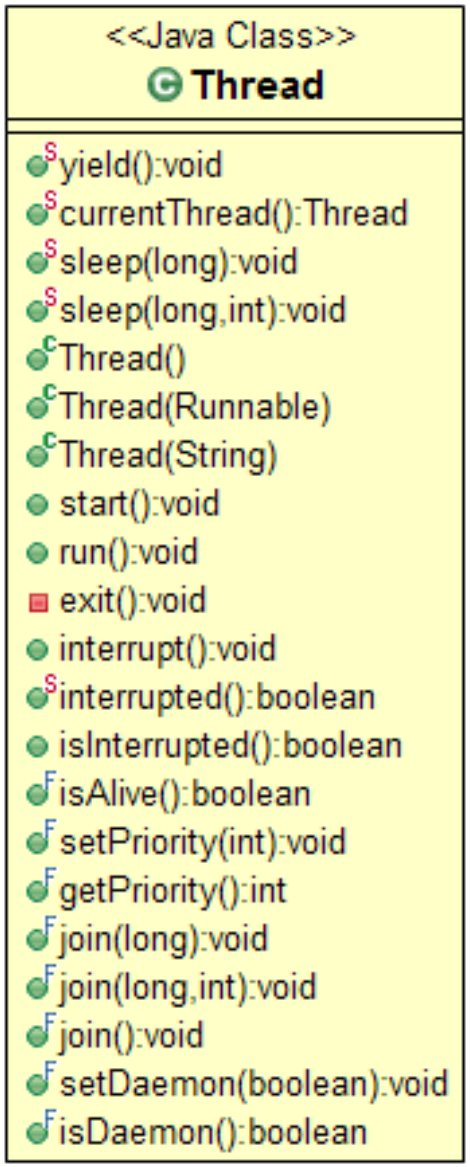
  - `void join()`
  - `void sleep(long time)`
  - **`Thread currentThread()`**
    - Object for current Thread



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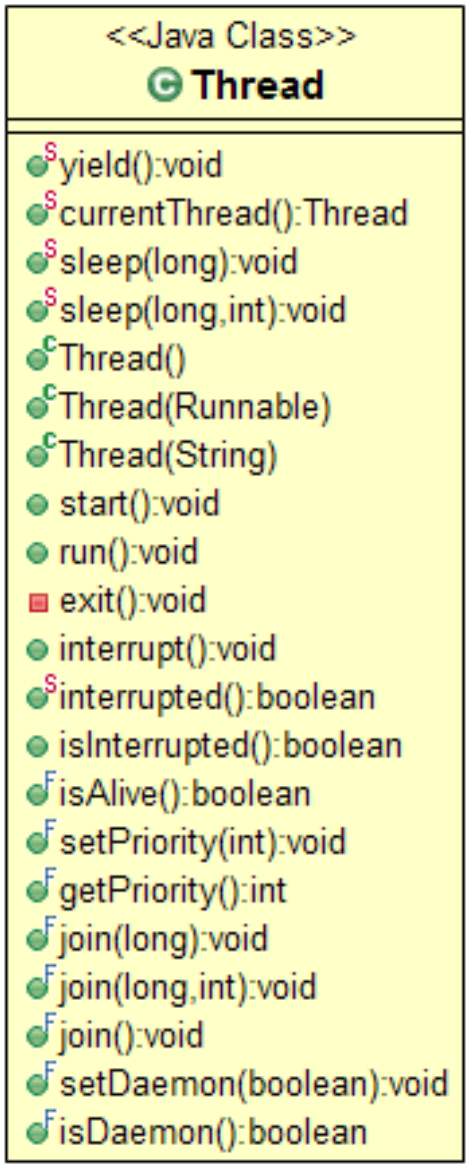
  - `void join()`
  - `void sleep(long time)`
  - `Thread currentThread()`
  - **`void interrupt()`**
    - Post an interrupt request to a Thread



See part 3 of upcoming lesson on "Managing the Java Thread Lifecycle"

Some Common Java Thread Methods

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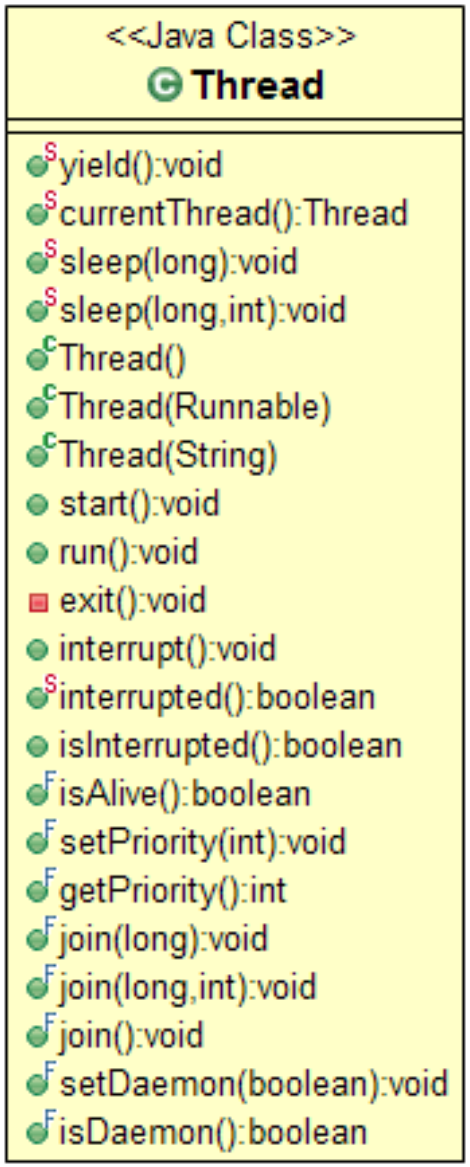
  - `void run()`
  - `void join()`
  - `void sleep(long time)`
  - `Thread currentThread()`
  - `void interrupt()`
  - **`boolean isInterrupted()`**
    - Tests whether a thread has been interrupted



isInterrupted() can be called multiple times w/out affecting the *interrupted status*

Some Common Java Thread Methods

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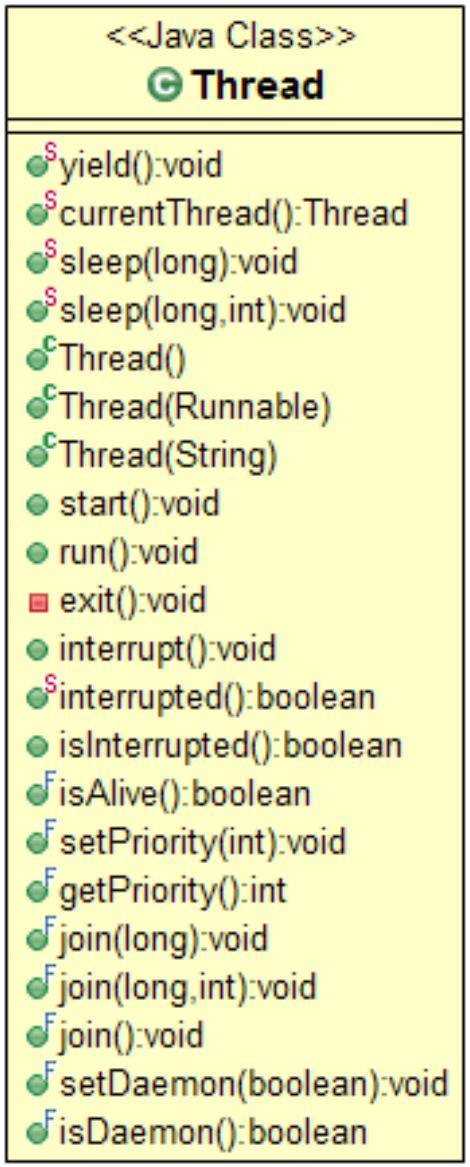
  - `void join()`
  - `void sleep(long time)`
  - `Thread currentThread()`
  - `void interrupt()`
  - `boolean isInterrupted()`
  - **`boolean interrupted()`**
    - Tests whether current thread has been interrupted



interrupted() clears the *interrupted status* the first time it's called

Some Common Java Thread Methods

- There are a number of commonly used methods in the Java Thread class, e.g.,
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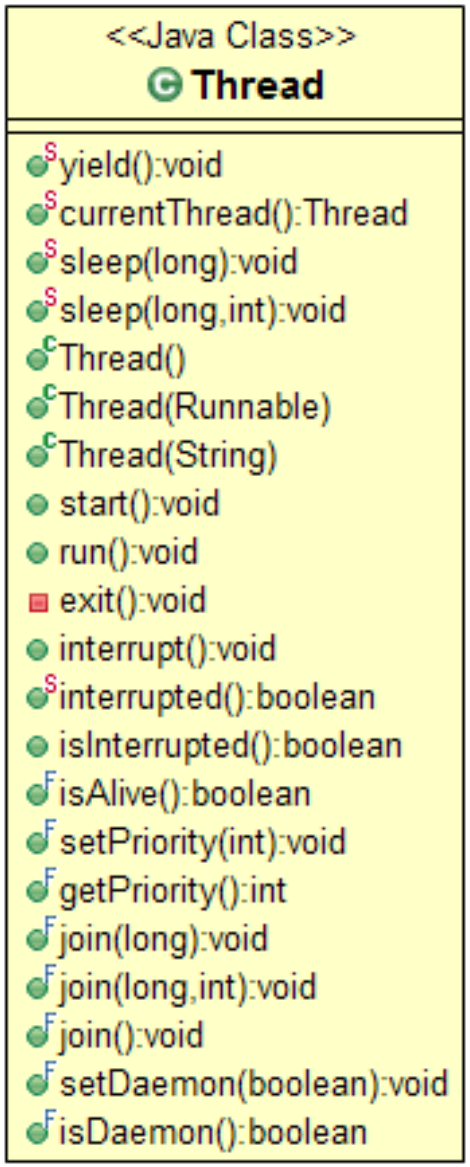
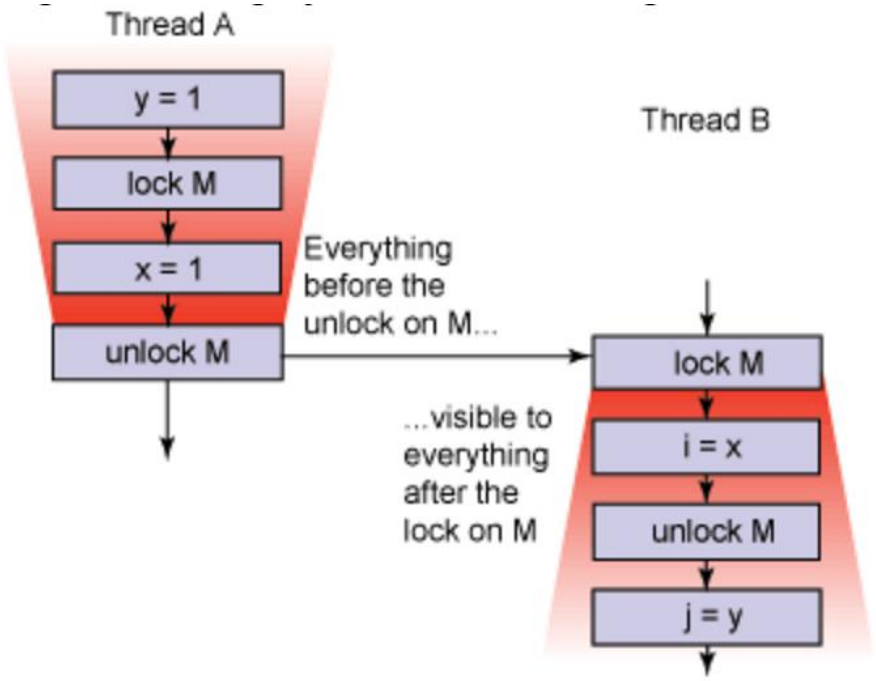
  - `void start()`
  - `void run()`
  - `void join()`
  - `void sleep(long time)`
  - `Thread currentThread()`
  - `void interrupt()`
  - `boolean isInterrupted()`
  - `boolean interrupted()`
  - **`void setPriority(int newPriority)`** & **`int getPriority()`**
    - Set & get the priority of a Thread



Java Thread "Happens-Before" Orderings

Java Thread "Happens-Before" Orderings

- Java Threads methods establish "happens-before" orderings



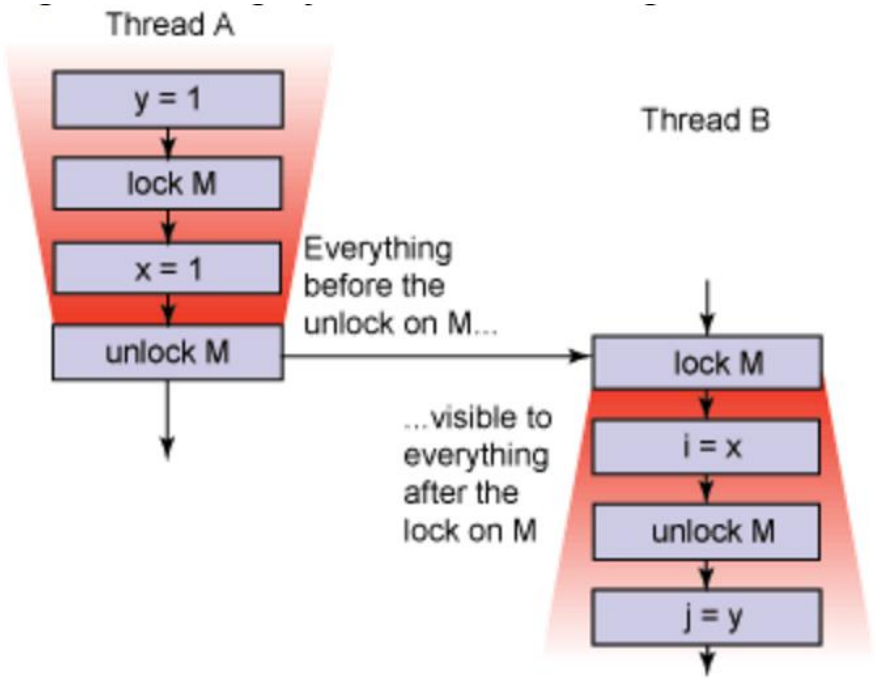
<<Java Class>>
Thread

- yield():void
- currentThread():Thread
- sleep(long):void
- sleep(long,int):void
- Thread()
- Thread(Runnable)
- Thread(String)
- start():void
- run():void
- exit():void
- interrupt():void
- interrupted():boolean
- isInterrupted():boolean
- isAlive():boolean
- setPriority(int):void
- getPriority():int
- join(long):void
- join(long,int):void
- join():void
- setDaemon(boolean):void
- isDaemon():boolean

See en.wikipedia.org/wiki/Happened-before

Java Thread "Happens-Before" Orderings

- Java Threads methods establish "happens-before" orderings
  - Ensure that if one event "happens before" another event, the result must reflect that, even if those events are actually executed out of order



<<Java Class>>
Thread

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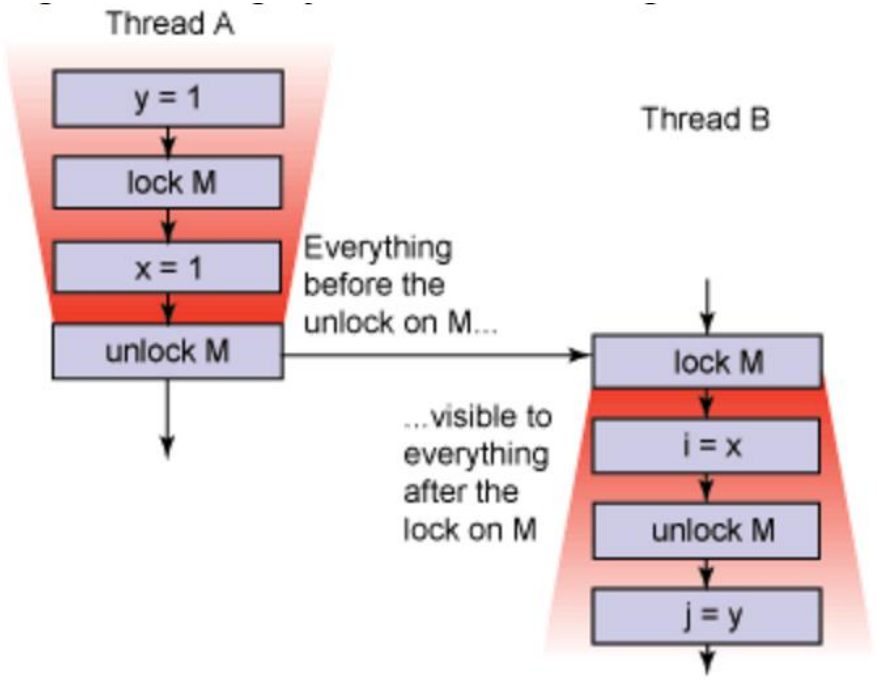
- Thread(String)
- start():void
- run():void
- exit():void
- interrupt():void
- interrupted():boolean
- isInterrupted():boolean
- isAlive():boolean
- setPriority(int):void
- getPriority():int
- join(long):void
- join(long,int):void
- join():void
- setDaemon(boolean):void
- isDaemon():boolean

See en.wikipedia.org/wiki/Happened-before

Java Thread "Happens-Before" Orderings

- Java Threads methods establish "happens-before" orderings
  - Ensure that if one event "happens before" another event, the result must reflect that, even if those events are actually executed out of order
    - e.g., to optimize program flow & concurrency

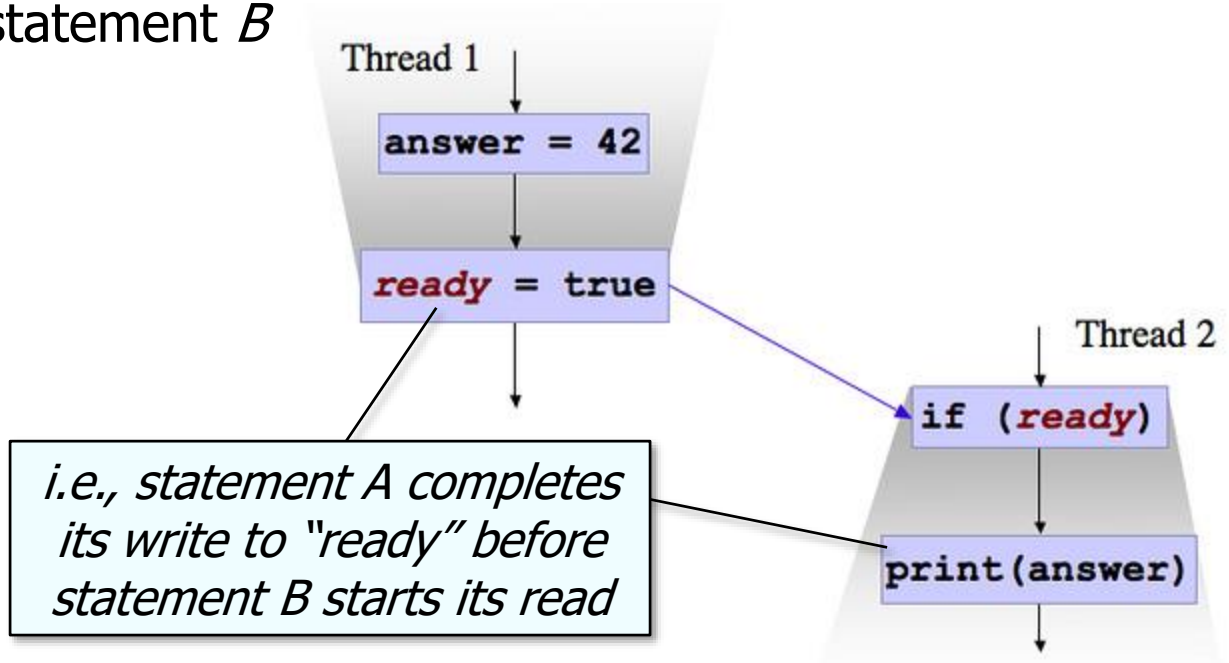


<<Java Class>>
Thread

- yield():void
- currentThread():Thread
- sleep(long):void
- sleep(long,int):void
- Thread()
- Thread(Runnable)
- Thread(String)
- start():void
- run():void
- exit():void
- interrupt():void
- interrupted():boolean
- isInterrupted():boolean
- isAlive():boolean
- setPriority(int):void
- getPriority():int
- join(long):void
- join(long,int):void
- join():void
- setDaemon(boolean):void
- isDaemon():boolean

Java Thread "Happens-Before" Orderings

- Java Threads methods establish "happens-before" orderings
  - Ensure that if one event "happens before" another event, the result must reflect that, even if those events are actually executed out of order
  - In general, a happens-before relationship guarantees that memory written to by statement *A* is visible to statement *B*



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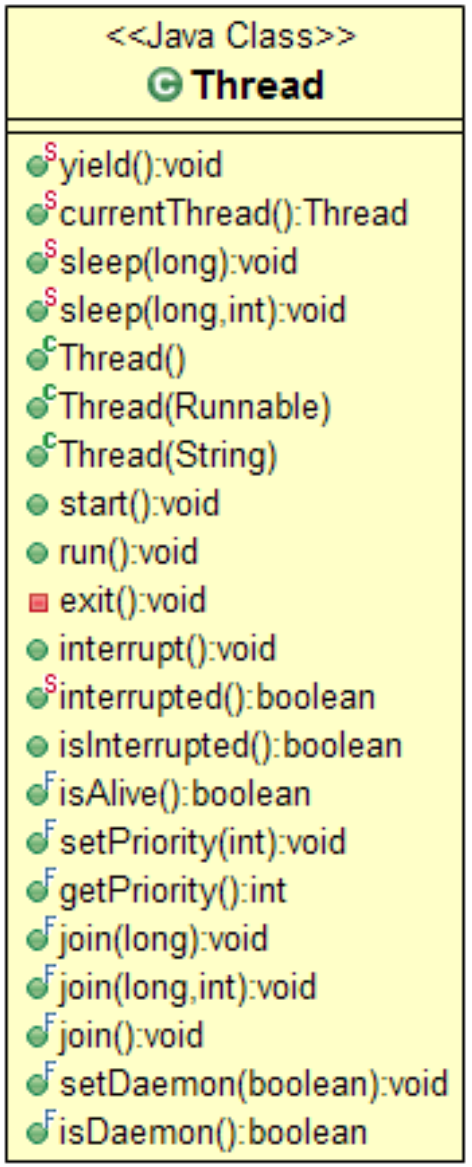
Java Thread "Happens-Before" Orderings

- Examples of "happens-before" orderings in Java

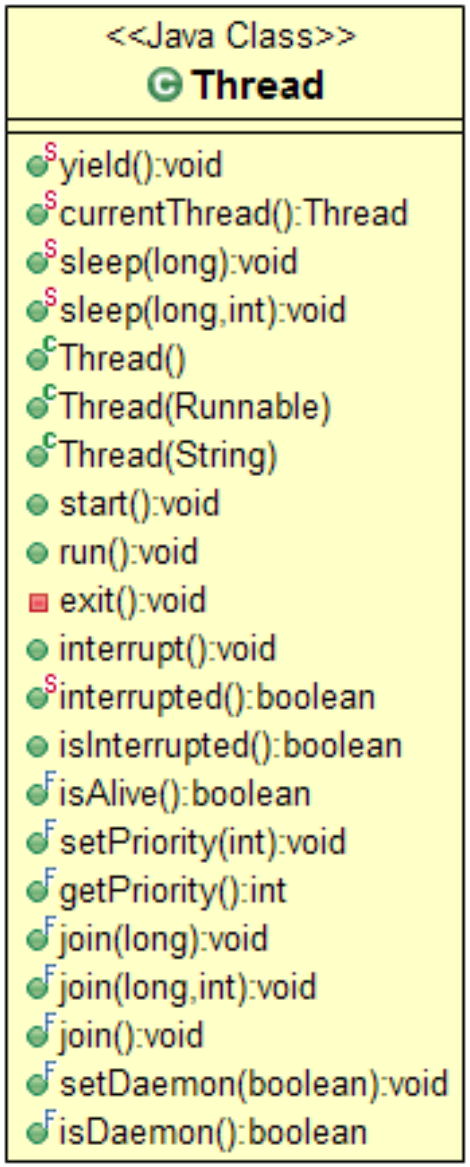


See en.wikipedia.org/wiki/Java_memory_model

Java Thread "Happens-Before" Orderings

- Examples of "happens-before" orderings in Java
  - Starting a thread "happens-before" the run() hook method of the thread is called

```
Thread t1 =
  new Thread(() ->
               System.out.println
                 ("hello world"))
    .start();
```

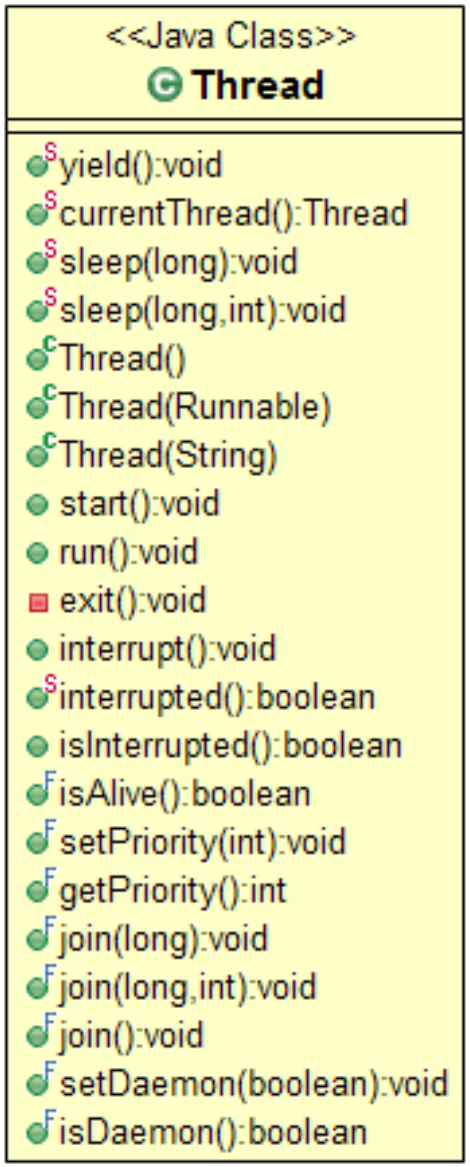


Java Thread "Happens-Before" Orderings

- Examples of "happens-before" orderings in Java
  - Starting a thread "happens-before" the run() hook method of the thread is called, e.g.

```
Thread t1 =
  new Thread(() ->
               System.out.println
                 ("hello world"))
    .start();
```

This lambda plays the role of the run() hook method!



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```
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    .start();
```
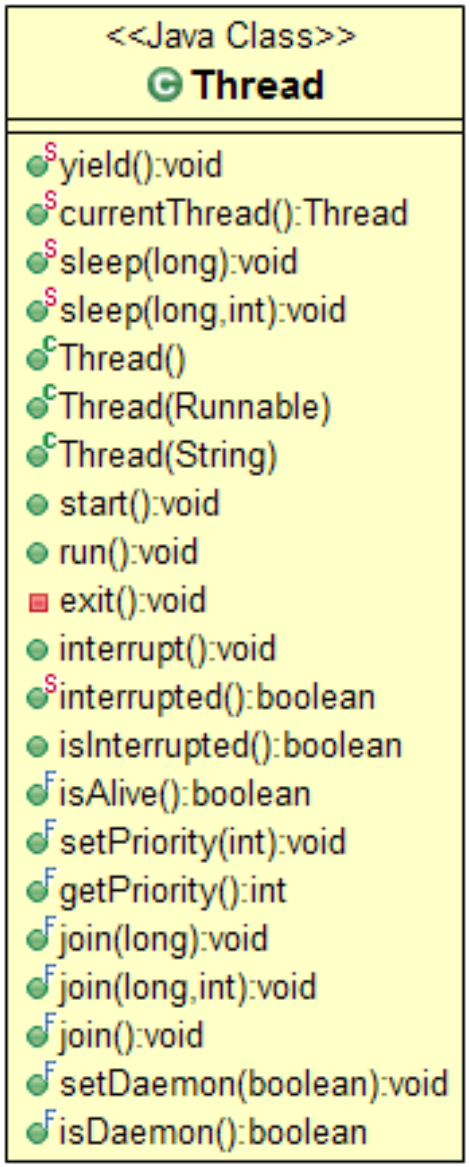
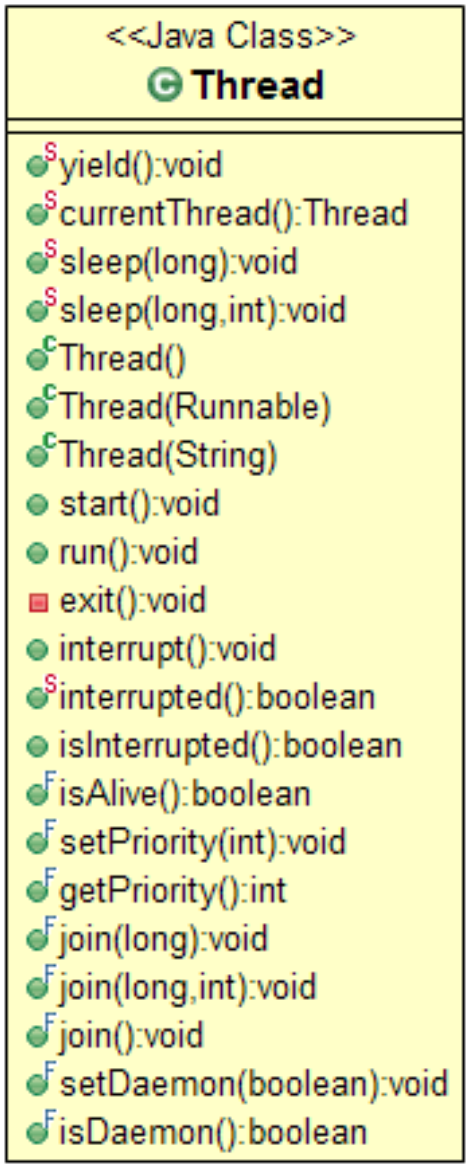

A thread's state is consistent & visible before run() starts



Java Thread "Happens-Before" Orderings

- Examples of "happens-before" orderings in Java
  - Starting a thread "happens-before" the run() hook method of the thread is called
  - Methods in java.util.concurrent package classes also establish "happen-before" orderings



See docs.oracle.com/javase/8/docs/api/java/util/concurrent/package-summary.html

Java Thread "Happens-Before" Orderings

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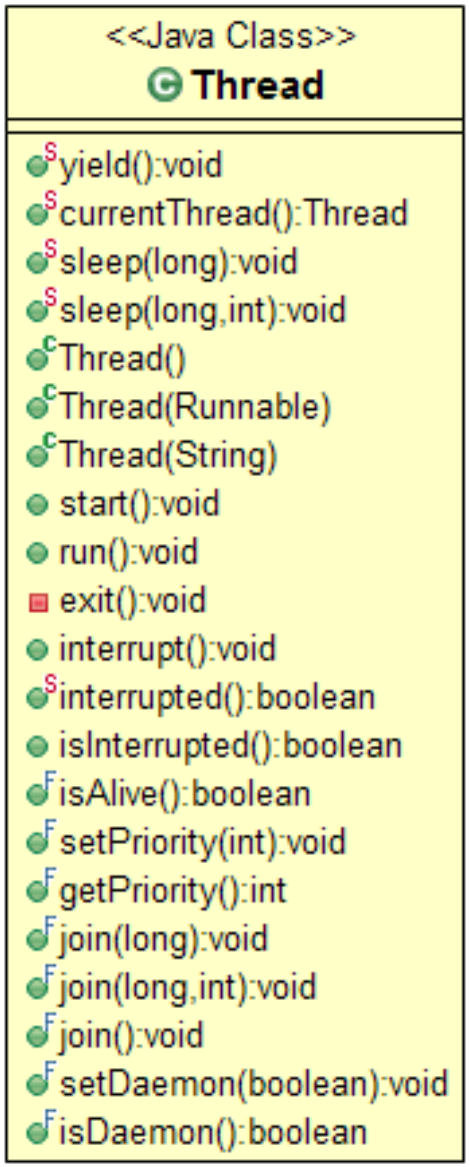
  - Starting a thread "happens-before" the run() hook method of the thread is called
  - Methods in java.util.concurrent package classes also establish "happen-before" orderings, e.g.

```
// Thread t1
ConcurrentMap concurrentMap =
  new ConcurrentHashMap();
concurrentMap.put("key", "value");

// Thread t2
Object value = concurrentMap.get("key");
```

Placing an object into a concurrent collection happens-before the access or removal of the element from the collection



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- Examples of "happens-before" orderings in Java
  - Starting a thread "happens-before" the run() hook method of the thread is called
  - Methods in java.util.concurrent package classes also establish "happen-before" orderings
  - The termination of a thread "happens-before" a join() with the terminated thread

```
Thread t1 =
  new Thread(() ->
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    .start();

t1.join();
```

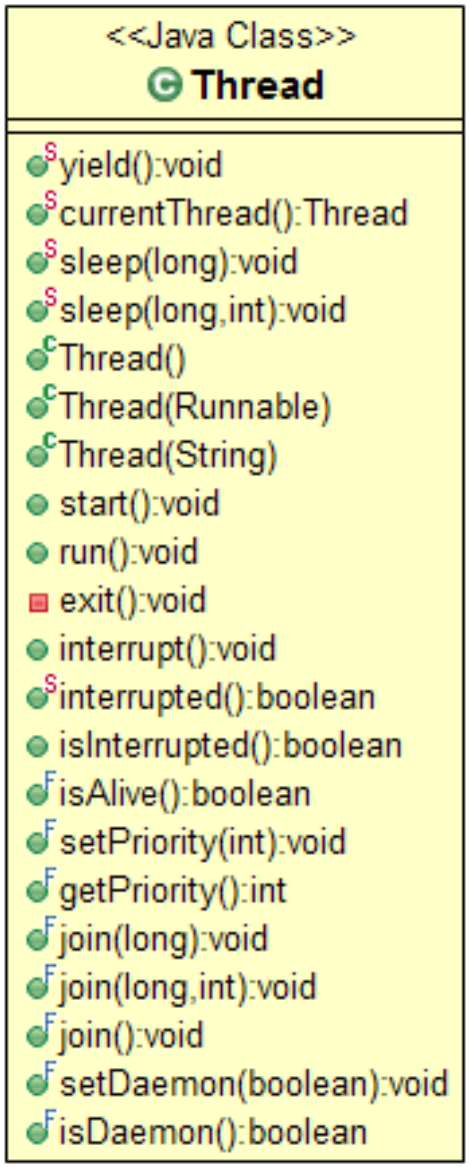

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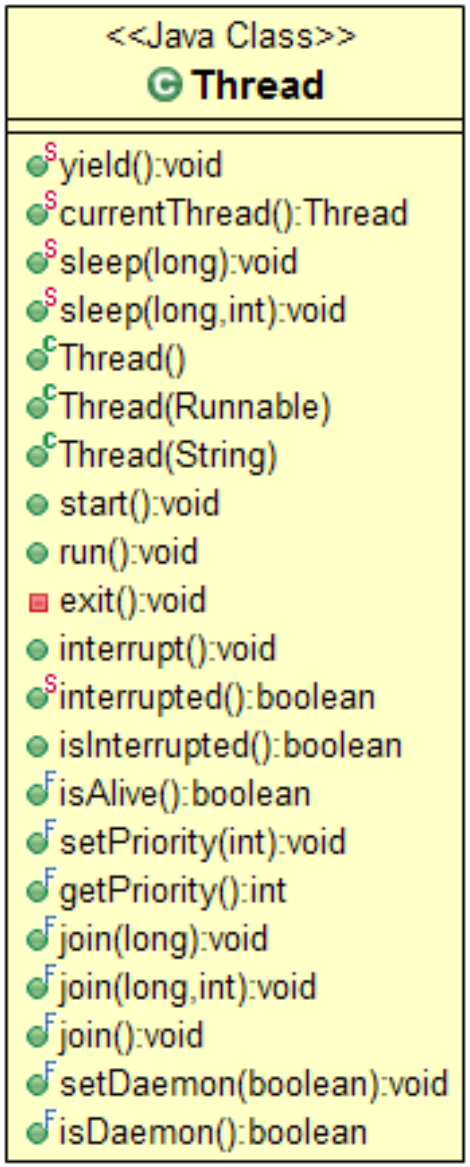
```
Thread t1 =
  new Thread(() ->
               System.out.println
                 ("hello world"))
    .start();

t1.join();
```

This thread terminates after its lambda expression runnable completes



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```
Thread t1 =
  new Thread(() ->
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                 ("hello world"))
    .start();

t1.join();
```
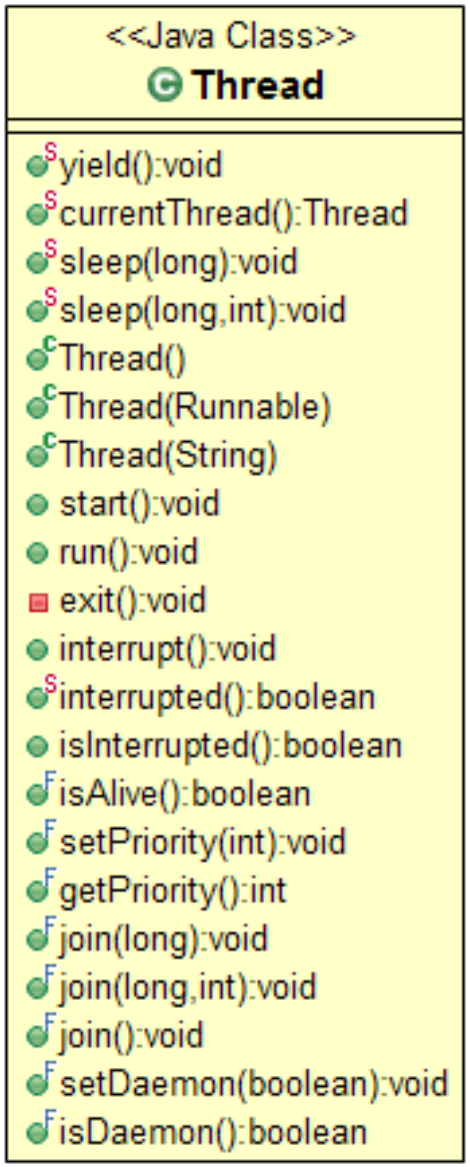
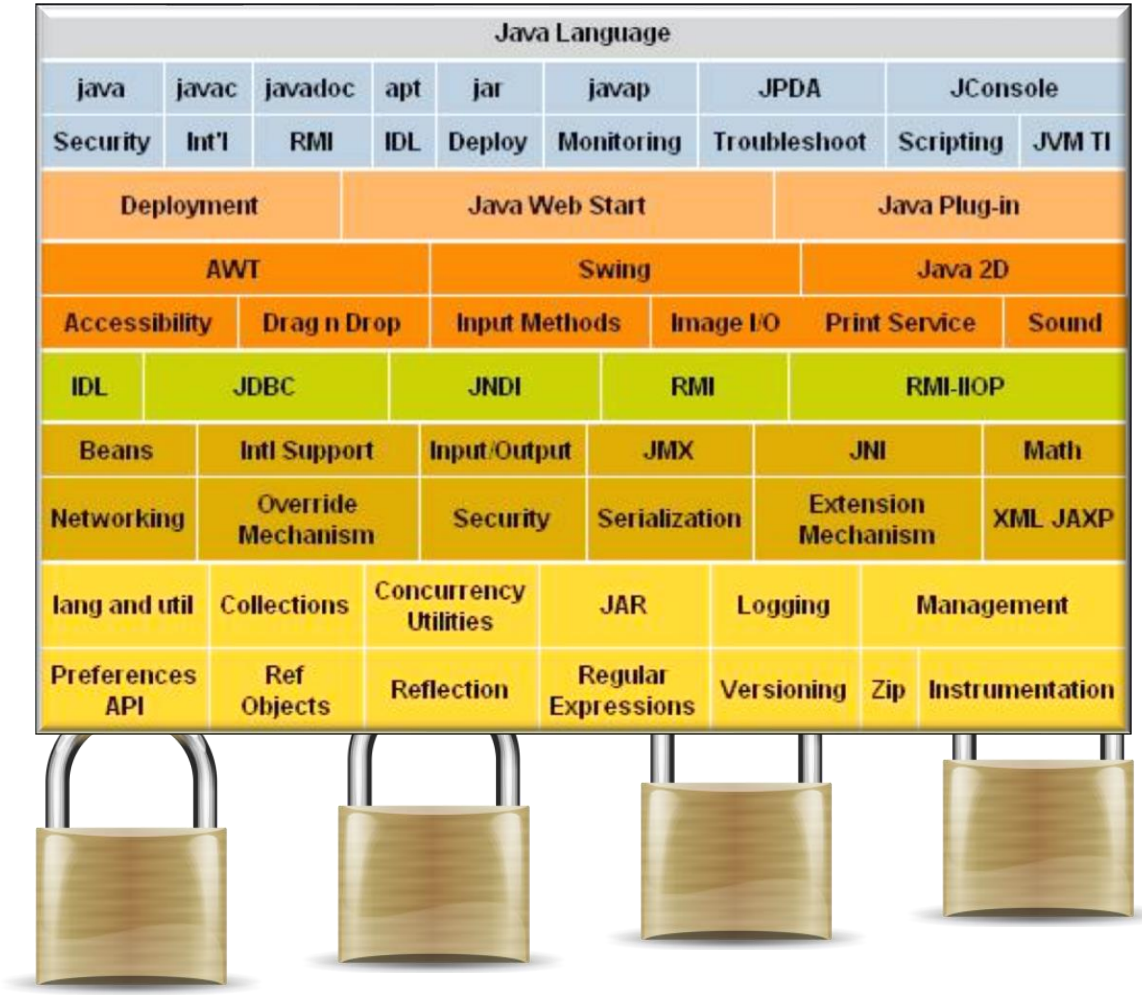

A thread waiting on a (non-timed) join() only resumes after the target thread terminates



Java Thread "Happens-Before" Orderings

- The implementations of these Java thread & library classes are responsible for ensuring that these "happens-before" orderings are preserved



You don't need to understand all the nitty-gritty details of Java's memory model – you just need to understand how to use synchronizers properly!

End of Overview of Java Threads (Part 2)

Discussion Questions

1. Which of the following are correct statements about the key differences between the Java Thread start() & run() methods?
   a. *The start() method sets the priority of the thread & the run() method allocates the thread's resources*
   b. *The start() method allocates the thread's resources & dispatches the join() method, which implements user-supplied code*
   c. *The start() method allocates the thread's resources & dispatches the run() method, which implements user-supplied code*
   d. *The start() method allocates the thread's resources & dispatches the run() method, which implements barrier synchronization*